SATELLITE METEOROLOGY IN THE COLD WAR ERA: SCIENTIFIC COALITIONS AND INTERNATIONAL LEADERSHIP 1946-1964

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LIST OF ABBREVIATIONS

ABMA	Army Ballistic Missile Agency	1956
AEC	Atomic Energy Commission	1946
AFB	Air Force Base	
AMS	American Meteorological Society	1919
AFCRC	Air Force Cambridge Research Center (Hanscom AFB)	
AFCRL	Air Force Cambridge Research Laboratories.	1952
APL	Applied Physics Lab, Johns Hopkins	1942
APT	Automatic Picture Transmission	
ARS	American Rocket Society	1934
ASRL	Army Signal Corps Research Lab (used for consistency) [1]	1917
ARPA	Advanced Research Projects Agency	1958
BRL	Ballistic Research Laboratory	
BUAER	Bureau of Aeronautics	1921
BUORD	Bureau of Ordnance	1862
CSAGI	IGY Special Committee (translated from French)	
DOC	Department of Commerce	1903
DOD	Department of Defense	1947
DOVAP	Doppler Velocity and Position	
ERB	Earth Radiation Budget	
ESSA	Environmental Science Service Administration Satellite	
ICAS	Interdepartmental Committee on Atmospheric Sciences	
ICBM	Intercontinental Ballistic Missile	
ICSU	International Committee of Scientific Unions[2]	1931
IGY	International Geophysical Year	1957-8
IMO	International Meteorological Organization[3]	1873
IR	Infrared	
IUGG	International Union of Geodesy and Geophysics	1919
GE	General Electric, Co.	1892
GRD	Geophysics Research Directorate (Hanscom AFB)	
JPL	Jet Propulsion Laboratory	1938
LPR	Long Play Rocket (euphemism for IGY satellite)	
NACA	National Advisory Committee on Aeronautics	1915

[1] The Signal Corps Radio Laboratories was opened at at Camp Vail in 1917, Camp Vail renamed Ft. Monmouth in 1925, 1930s consolidation of labs resulted in 1930 renaming to Signal Corps Laboratories, 1941 SCL relocated to Camp Evans (near Ft. Monmouth). In 1945 they reorganized and were referred to as the Signal Corps Engineering Lab (SCEL) or Evans Signal Laboratory (ESL).

[2] Predated by International Association of Academies (1899-1914) and International Research Council (1919-1931).

[3] Replaced by World Meteorological Organization (WMO) in 1951

NAS	National Academy of Sciences	1863
NASA	National Aeronautics and Space Administration	1957
NBS	National Bureau of Standards	1901
NCAR	National Center for Atmospheric Research	1960
NRL	Naval Research Laboratory	1923
NSF	National Science Foundation	1950
NOTS	Navy Ordnance Test Station	1943
ONR	Office of Naval Research (preceded by ORI)	1946
ORI	Office of Research and Invention	1945
PSAC	President's Science Advisory Committee	1951
RAND	Research And Development Project, RAND Corporation	1946, 1948
RADAR	Radio Detection and Ranging	
RCA	Radio Corporation of America	1919
RSRP	Rocket and Satellite Research Panel	1955-60
SCEL	Signal Corps Engineering Laboratory, see ASRL	1945
SAC	Strategic Air Command	1946
T-Day	Temperature Day	
TIROS	Television InfraRed Observation Satellite	
TOS	TIROS Operational System (also ESSA)	
TPESP	IGY Technical Panel on Earth Satellite Program	
UARRP	Upper Atmospheric Rocket Research Panel	1948-57
UCAR	University Committee on Atmospheric Research	1958
URSI	International Radio Science Union (French acronym)	1919
USIA	US Information Agency	1953
USWB	United States Weather Bureau	1870
UN	United Nations	1945
V-2	Vergeltungwaffe 2 (Vengeance Weapon 2)	
WBAN	Weather Bureau, Army, Navy/WB Air Force Navy	
WMO	World Meteorological Organization	1951
WWW	World Weather Watch	1962-3

SUMMARY

In tracing the history of the TIROS meteorological satellite system, this dissertation details the convergence of two communities: the DOD space scientists who established US capability to launch and operate these remote sensing systems and the US Weather Bureau meteorologists who would be the managers and users of satellite data. Between 1946 and 1964, these persons participated in successive coalitions. These coalitions were necessary in part because satellite systems were too big—geographically, fiscally, and technically—to be developed and operated within a single institution.

Thus, TIROS technologies and people trace their roots to several research centers—institutions that the USWB and later NASA attempted to coordinate for US R&D. The gradual transfer of persons and hardware from the armed services to the non-military NASA sheds light on the US's evolution as a Cold War global power, shaped from the "top-down" (by the executive and legislative branches) as well as the "bottom-up" (by military and non-military scientific communities).

Through these successive coalitions, actor terms centered on "basic science" or the circulation of atmospheric data were used to help define bureaucratic places (the Upper Atmospheric Rocket Research Panel, International Geophysical Year, NASA, and the World Weather Watch) in which basic research would be supported by sustained and collaboration could take place with international partners.

CHAPTER 1 INTRODUCTION:
From Cornerstones of National Defense to Global Scientific Instrument

In September 1966, the Lyndon B. Johnson White House circulated a press release announcing, "plans for US participation in the World Weather Watch—one of the boldest and most complex scientific programs ever attempted as an international effort." The brief explained that the President had directed eight federal agencies to engage in an international effort to establish a cooperative, worldwide weather service. As such, it incorporated scientific and technological advances on a scale "no nation could undertake alone."[1] Indeed, the World Weather Watch (WWW) network routed an unprecedented volume of environmental observations from meteorological satellites, weather buoys, automated weather stations, and hundreds of observer posts from across the globe in the interest of routine weather forecasting as well as amassing data for basic scientific research. Upper atmospheric research had unquestionably achieved the status of "Big Science."

To many, "talking about the weather" seemed perhaps the most benign if not banal exchange possible. Since 1873 the International Meteorological Organization and its successor, the World Meteorological Organization had coordinated national weather service observations, helped standardize meteorological practice, and conducted special

[1] Draft Press Release, 19 September, 1966, file: Meteorological Weather Link, box: 15 National Security File of Charles E. Johnson, Lyndon Johnson Presidential Library (hereafter, Johnson Papers).

research projects.[2] By the mid-twentieth century, their efforts had brought forth growing participation of national weather services, including in Europe, the postcolonial world, parts of eastern and western Asia, and the Soviet Union.

But talking about the weather could be problematic. The WMO's gradual expansion was punctuated by world wars, regional conflicts, and other geopolitical strife when adversaries (US policy included) denied the international organization their local weather observations.[3] The international network was composed of, unforgivingly, *national* units of participation. Due to the fact that this observation network relied on state participation for human resources, funding, and international legitimacy as a UN operating agency, it remained at least marginally at the mercy of political considerations.

Weather observations are "dual use" in nature— a valuable service to the public, but also the military. Observations from a satellite might be used to advance scientific knowledge of the atmosphere or be applied to forecasting, both of which are useful to both military and non-military communities. Satellites, themselves dual use products of national defense complexes, revealed new complexities to international exchanges of

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[2] Frederik Nebeker. *Calculating the Weather: Meteorology in the 20th Century* (New York: Academic Press, 1995), 87-88, Paul Edwards, "Meteorology as Infrastructural Globalism," in *Global Power Knowledge: Science and Technology in International Affairs (Osiris*: 21*).* Paul Edwards, "Representing the Global Atmosphere: Computer Models, Data, and Knowledge about Climate Change," in Clark Millar and Paul Edwards (eds), *Changing the Atmosphere: Expert Knowledge and Environmental Governance* (Cambridge, Mass: MIT Press, 2010.)
[3] Edwards, "Meteorology as Infrastructural Globalism." To learn more about Reichelderfer's war years, coordinating data and coping with wartime interruptions to international exchange, see Kathleen Broome Williams, *Improbable Warriors: Women Scientists and the US Navy in World War II* (Annapolis, MD: US Naval Institute Press, 2001), 72-76.

atmospheric data.[4] Not only did these emerging technologies promise to become the most complicated and the most expensive instruments used for studying the earth's atmosphere, they were the most politically charged. The capacity to launch them evoked the fear of nuclear holocaust; they challenged long-standing conceptions of national sovereignty and airspace; and they were so expensive, they could only be justified in terms of national security or prestige (itself a function of Cold War national security.)[5]

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[4] For histories regarding the "dual use" nature of remote sensing equipment in military and/or civilian meteorology see: John Cloud "Imaging the world in a Barrel," "Cold War Science in Black and White," Pam Mack, *Viewing the Earth: The Social Construction of the Landsat Satellite System* (Cambridge, Mass: MIT Press, 1990), David DeVorkin "Who Speaks for Astronomy? How Astronomers responded to government funding after World War Two," *Historical Studies in the Physical and Biological Sciences* 31, no. Part I (2000): 55-92. "Cold War Science in Black and White: US Intelligence Gathering and its Scientific Cover at the Naval Research Laboratory, 1948-62," *Social Studies of Science* 31 (2001) pp. 207-229. James Rodger Fleming, *Fixing the Sky: the Checkered History of Weather and Climate Control* (New York: Columbia University Press, 2010), 165-188. Erik Conway, "The World According to GARP: Scientific Internationalism and the Construction of Global Meteorology, 1961-1980," in Margaret Vining and Barton Hacker (eds), *Science in Uniform, Uniforms in Science (*Lanham, Maryland: Scarecrow Press, 2007), Ronald Doel and Kristine Harper, "Prometheus Unleashed: Science as a Diplomatic Weapon in the Lyndon Johnson Administration," *Osiris 21,* Kristine C. Harper, "Boundaries of Research: Civilian Leadership, Military funding, and the International Network Surrounding the Development of Numerical Weather Prediction in the US," (PhD diss., Oregon State University, 2003), Kristine Harper, *Weather by the Numbers: the Genesis of Modern Meteorology* (Cambridge: MIT Press, 2008).

[5] There were many linkages in press and politics regarding the inaccurate presumption that if the Soviet Union was capable of launching a satellite in orbit, it could be equated with the ability to accurately launch an ICBM at the United States. In fact, Asif Siddiqi notes that the first successful launch of an R-7 ICBM occurred on Aug 21, 1957, roughly six weeks before Sputnik. In an unusual act of publicizing a military achievement, Soviet authorities communicated the successful launch of a "super-long-range, intercontinental ballistic missile" at a "hitherto unattained altitude." However the US press demonstrated little, if any interest. See Asif Siddiqi, *Sputnik and the Soviet Space Challenge* (Gainesville: University of Florida Press, 2000),161-162.

Reconsidering classic narratives of superpower rivalry, this study maps how contrary to experience in past geopolitical conflicts, US and Soviet Cold War statesmen aligned state policy with the desires of scientific practitioners to greatly enhance, and in time*, stabilize* the international circulation of upper atmospheric observations in the International Geophysical Year (IGY) and later World Meteorological Organization (WMO). Shortly after construction of the Berlin wall and just a few months before the Cuban Missile Crisis, representatives of the US and Soviet scientific communities met to discuss trading meteorological satellite data. In many regards, President John F. Kennedy and Premier Nikita Khrushchev's agreement to trade weather satellite data was intended as a diplomatic gesture to garner international goodwill and relieve global tension. This dissertation details the many years of policymaking and scientific precedent that rendered their highly politicized offer technically and practically viable. The blessing of heads of state was necessary for the US scientific community to share weather satellite images with Soviet partners. Once the Kennedy administration had secured Khrushchev's commitment to the project, the US Weather Bureau (USWB) and National Aeronatics and Space Administration (NASA) could begin expanding upon a bilateral mandate and establish a world order for trading satellite data as well as more traditional atmospheric observations already being circulated in the World Meteorological Organization.

As Chapter One's title indicates, this dissertation is about getting to the global. At a series of junctures in this dissertation, the delineation of activities or institutions as being involved in or performing basic research or other activities specifically not directed toward developing military applications instituted bureaucratic "places" as more neutral "trading zones."[6] Through these research activities, sounding rocket and satellite technologies (read: missile and reconnaissance technologies) were transferred first out of the field of missile science. Meteorological instruments were transferred to use in a scientific earth satellite system supporting earth science research in the International Geophysical Year (IGY), then transferred to NASA, and finally used for cooperation in the United Nation's World Meteorological Organization's World Weather Watch.

[6] Peter Galison, "Trading Zone: Coordinating Action and Belief," in Mario Biagioli, ed, *The Science Studies Reader* (New York: Routledge, 1999), pp. 137-160. Galison characterizes interactions among three subcultures of physics including instrumentation, experimentation, and theory. While these subcultures of the physics community attach different meaning to trading zone objects, they can collaborate and come to consensus on procedures. Galison states that continuous exchange is necessary for the survival of the physics culture.

Table 1.1 Chapters and R&D Coalitions

	Basic Research Coordinated	Yielded	International Inputs
Chapter Two UARRP 1945-1958	DOD labs', universities' sounding rocket payloads and launch	New technologies, new altitudes	Project Paperclip Germans, UARRP active in International Scientific Unions, competition with Soviet Union a driver in R&D
Chapter Three IGY 1957-1958[7]	Mix of 67 countries' armed services, research institutions, weather services UARRP and NAS coordinated for Vanguard satellite	New technologies, new (but temporary) geopolitical accesses to data, access to satellite orbit Skills for satellite design and launch; no follow-on program	67 nations coordinated observations and shared data; Sputnik shock led in part to NASA formation
Chapter Four NASA 1958+	Basic research supports DOD and civilian applications; nonmilitary R&D hardware	Sustained support for basic research and civilian R&D, this sustained US research and researchers from IGY But DOD has TIROS meteorological satellite program	NASA mandate to perform international cooperation; establish US leadership
Chapter Five TIROS 1958[8] NCAR 1960+	NASA coordinates national met sat system, USWB performs data-handling	Transferred DOD's TIROS technology and DOD funds to NASA	Tracking stations across globe, cloud imagery shared with international partners, training in interpretation of cloud images
Chapter Six WWW 1962[9]	WMO member nations' data from satellites and synoptic stations; TIROS Operational Satellite System	Operational satellite systems, sustained access, orders of magnitude more data	By 1975, 135 countries contributing resources and data

Tracing the evolution of a remote sensing system through five phases, this dissertation documents the means by which a succession of coalition interest groups

[7] Extended so that it lasted from the summer of 1958 through the end of 1959.
[8] Planning began in 1958, transferred to NASA 1959, launched 1960.
[9] Planning began 1962, operational 1964.

negotiated with executive and legislative authorities to reshape US science and technology policy. [10] This, in turn, shaped US international relations. Intervening at critical junctures, the researchers and middle management featured here established that select UARRP environmental observations produced by military sounding rockets would be treated as basic research, and therefore limited as little as possible by classification restrictions (Chapter Two). Whereas the Eisenhower Administration intended for the US's first satellite to be an inexpensive and simple "stalking horse"[11] to assure the US's right to satellite overflight of foreign territory, sounding rocket and satellite researchers worked to ensure that the US's first satellite establish *scientifically relevant* precedents of data circulation and develop a satellite system with more experiments and more capabilities. All of these resulted in a higher cost than desired by the Eisenhower Administration, but sustainable infrastructure (Chapter Three). Post-Sputnik, a couple dozen IGY rocket and satellite researchers consulted with Congress and the White House over the formation of a National Space Establishment, pointing out how basic research performed in a non-military establishment would support US defense activities in space but also US and international civil society.[12] Many of these persons then transferred to the newly formed non-military research centers of NASA (Chapter Four). Long alarmed by the perceived encroachment of defense research and development (R&D) funding into

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[10] Remote sensing is broadly defined today as a method of obtaining information about the properties of an object without coming into physical contact with that object. AMS Glossary of Meteorology http://glossary.ametsoc.org/wiki/Remote_sensing

[11] Allan Needell, *Science, Cold War, and the American State: Lloyd V. Berkner and the Balance of Professional Ideals* (Australia: Harwood Academic Publishers, 2000), 325. See also Cargill Hall in NASA *Exploring the Unknown Vol. I: Organizing for Exploration* (Washington, D.C.; NASA SP 4407), 222.

[12] These key representatives of the budding space science community wrote two well-circulated proposals for a National Space Establishment. See Appendix B for one proposal and list of signers.

civilian spheres of influence (in particular the universities and basic research) Weather Bureau administrators labored to assert their own percieved federal mandate to perform basic research. USWB officials began taking aggressive strides in 1957 and 1958 to establish the US Weather Bureau as the central power acquiring and routing meteorological satellite data. At this time, NASA officials actively sought transfer of the department of defense's experimental meteorological satellite system to NASA (Chapter Five). Between 1962 and 1964, NASA and USWB officials expanded upon a presidential *bilateral* mandate to trade weather satellite observations with the Soviet Union, committing the US to a position of leadership in the formation of a *multilateral* WWW (Chapter Six). Through these successive steps, cornerstones of US national defense—including reconnaissance satellite cameras, missile tracking technologies, ICBM launch vehicles, and hundreds of scientists and engineers were re-mobilized under wholly new organizational logics.

From the perspective of the meteorological community and the rocket and satellite R&D communities, these steps were not viewed as a means of regulating military power, nor taken at the expense of tactical capabilities. Indeed, data from research conducted in the International Geophysical Year and World Weather Watch supported "hard power" activities inherent to Strategic Air Command, reconnaissance satellite operations, tactical operations in the field, and for working up weather forecasts concerning forward operating bases and enemy territory abroad.[13] The resulting network

[13] Hard power is most broadly characterized as military or economic might, as either carrot-inducements or stick-threats. Joseph Nye, former Assistant Secretary of Defense contrasts hard power with soft power. Nye describes soft power as being co-optive power, the ability to shape what others want. Joseph Nye, *Soft Power: the Means to Success in World Politics* (New York: Public Affairs, 2004), 5-7.

increased the circulation of atmospheric observations. It secured more resources for non-military institutions such as the USWB, the University Center for Atmospheric Research, and the National Center for Atmospheric Research; it sustained input from the US armed services; and it greatly increased data circulation among the US and World Meteorological Organization partners.

The Meteorologists and the Space Science Community 1946-1958

This study tracks a decade-long interplay between the meteorological community and the space science community before their interests converged in a national meteorological satellite system in 1958. From 1946 through 1958, the US space science community developed a variety of launch systems and scientific instruments, used for observing the upper atmosphere.[14] During this time the meteorological community recognized the promise of very high altitude observations, but did not pursue the resources for their own rocket and satellite systems, distinct of military labs. The space science community for their part remained open to observers of panel proceedings and readily shared observations in the scientific press as well as personal correspondence.

By the phrase "space science community," I refer to a series of coordinating panels that designed, constructed, experimented with, and operated sounding rockets and

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[14] Homer Newell, who would serve as NASA's assistant director for space sciences, deputy director for spaceflight programs, director for space sciences, associate administrator for space science and applications, and finally associate administrator of NASA defines space science as "*scientific investigations made possible or significantly aided by rockets, satellites, and space probes.*" Historian David DeVorkin has explained how over these years the rocket research communities transitioned from being more developmentally-oriented, honing the engineering skills to launch instruments into the upper atmosphere and how later, their scientific findings came to be accepted by more established scientific communities. David DeVorkin, *Science with a Vengeance: How the Military Created the US Space Sciences After WWII* (New York: Springer Verlag), 1992.

later satellites. One panel (see Appendix A for details on member institutions and Panel interests over time) changed names three times without drastically changing composition or mission. In 1946 it began as the V-2 Rocket Research Panel, so named because the US Army had invited university, federal, and industry researchers to place scientific instruments in the nose cones of captured German V-2s. The Panel flourished and, due to the dwindling number of V-2s and proliferation of alternative sounding rockets, changed its name to the Upper Atmospheric Rocket Research Panel in 1948. In 1955, the Panel changed its name again when its members began coordinating contributions for the IGY Vanguard satellite.[15] The Rocket and Satellite Research Panel (RSRP) lasted until 1960 when its members had completed their International Geophysical Year work and NASA had superseded its function coordinating launch services with the scientific communities interested in sending research equipment into the upper atmosphere and earth orbit.[16]

Throughout scientific explorations and observations in the International Geophysical Year, the RSRP functioned as node around which various research communities coordinated resources and operations. Central to the RSRP activities were sounding rocket flights and later, the design and operation of the Vanguard and Explorer satellite systems. In 1958 the entire Vanguard team, their satellite support systems, and the remaining satellite manifest was transferred by executive order to NASA, composing

[15] Vanguard was by definition an interservice project with Army and Navy contributions, but managed by the Naval Research Laboratory's Vanguard Division.
[16] The IGY began in 1957 and was extended to last through 1959. During this time sixty-seven nations coordinated geophysical observation of the earth, sharing data and circulating their findings in national and international publications and meetings. The Sputnik, Vanguard, and Explorer satellites were all Soviet and US contributions to the IGY. Numerous sounding rocket experiments were also conducted during this time.

the nucleus of what would become NASA's Goddard Spaceflight Center.[17] In 1959, NASA's Vanguard Division began to advise NASA Administrator Keith Glennan on the transfer of the military meteorological satellite system TIROS, to NASA for launch and operation.[18]

Cooperation between the space science communities and the meteorological community came slow and uncertainly. Between 1946 and 1958, the space science research community (from the V-2 Panel to the RSRP) had performed R&D and sought to keep it not only unclassified but also circulating in the scientific literature and at professional conferences. A variety of professionals participated in Panel research including rocket engineers, radio physicists, mathematicians, upper atmospheric physicists, electrical engineers, chemists, and a limited number of meteorologists. In some regards the space science community overlapped with the "meteorological community." Bridging these two—one primarily military and the other primarily civilian—were two now largely obsolete classifications of research, aerology and aeronomy. Aerology was defined as the meteorology of the free atmosphere above approximately 20 meters and extending throughout its vertical extent.

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[17] John E. Naugle, *First Among Equals: The Selection of NASA Space Science Experiments* (Washington, D.C.: NASA SP 4215, 1991), Homer Newell, *Beyond the Atmosphere: Early Years of Space Science* (Washington, D.C.: NASA SP-4211, 1980), *Dreams, Hopes, Realities: NASA's Goddard Space Flight Center First Forty Years* (Washington, D.C.: NASA SP-4312), Alfred Rosenthal, *Venture into Space: Early Years of Goddard Space Flight Center* (Washington, D.C.: NASA SP-4301), Linda Newman Ezell, *NASA Historical Data Book II Programs and Projects 1958-1968* (Washington, D.C.: NASA SP-4012), Lane Wallace, *Dreams, Hopes, Realities: NASA's Goddard Space Flight Center the first forty years* (Washington D.C.: NASA History Office, 1999). NASA SP-4312. The October 1 formation of NASA transferred 157 Vanguard personnel from NRL to NASA. Later 47 scientists from NRL's sounding rocket branch transferred and 15 from NRL's Theoretical Division came. The April 1959 transfer of Army Signal Corps TIROS team is listed as the last of the initial cadre at GSFC, p18-19.

[18] See Chapter Five.

Aeronomy was a second important classification of research at that time overlapping with meteorology. Aeronomy refers to the physics and chemistry of the upper regions of the atmosphere where ionization, dissociation, and a number of chemical reactions take place.[19] This "atmospheric shell" undulates according to variances in day and night, solar activity, and geomagnetism. Well into the 1960s, researchers could not determine the highest point of the ionosphere, but they had identified its lowest dip as low as 40 to 49 miles (70 to 80 kilometers). Whereas lower frequency radio waves are unaffected by the ionosphere, higher frequency waves can be reflected back to earth by this "shell." This "skip-distance effect" identified at the turn of the twentieth century can propagate radio waves to receivers hundreds and thousands of miles away. Thus the chemical and electromagnetic properties and patterns of undulation of the ionosphere were of great interest to the armed services for communications, missile tracking, missile guidance, reconnaissance, and countermeasures.

Meteorologists such as Army Signal Corps' William Stroud and RAND Corporation's William Kellogg were keenly interested in this region of high ion density and attempted to incite the interest of fellow meteorological researchers. Perhaps the most vivid (and witty) description of ionospheric studies came from Kellogg speaking to a joint meeting of American Meteorological Society and American Geophysical Union:

> The same atmosphere which, by absorption, protects us from the powerful radiation coming from outside [solar and cosmic radiation], is also the obstacle which hinders us from looking into outer space. In particular, the very important

[19] An alternative definition: "As officially used in the US Navy until early 1957, same as meteorology; this usage was more administrative than scientific." *Dictionary of Technical Terms for Aerospace Use, First Edition,* (Washington, D.C.: NASA SP-7, 1965).

> region of the ionosphere which is formed by the ultraviolet and x-ray radiation coming from the sun, acts as an "ion-curtain" beyond which we cannot see.[20]

Individuals from the Rocket and Satellite Research Panel attended American Meteorological Society (AMS) meetings and published in the AMS-affiliated journals. William Stroud designed meteorological instruments that flew on RSRP rockets, orbited on IGY satellites, and functioned as key instruments of NASA's TIROS weather satellite system. Kellogg wrote several influential reports and proposals regarding applications of meteorological instruments to spaceflight in the 1950s and took a keen interest in better coordinating research activities between the USWB and RSRP. Yet, until roughly 1954, the USWB remained willfully in the margins of space science research, doubtful of the operational utility of either satellites or sounding rockets in the immediate future, but also lacking the resources to take an active role in the field.[21] For instance, USWB researcher Harry Wexler attended Rocket Panel meetings regularly, not representing the Bureau, but as a representative of the National Advisory Committee for Aeronautics, for which he chaired National Advisory Committee on Aeronautics (NACA) special subcommittee on the upper atmosphere.[22] Neither the USWB nor the NACA were formally identified as

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[20] "Use of an Artificial Satellite in Upper Air Research" H. K. Kallmann and W. W. Kellogg RAND Report P-760 February 15, 1956 as presented at National Meeting of the American Meteorological Society held in New York, January 23, 1956. Available at www.DTIC.mil.

[21] Chapters Two and Three illustrate that USWB researchers and administration were interested in both satellites and sounding rockets as early as the 1940s, but considered them impractical from a budgetary standpoint.

[22] On Wexler see J. Fleming, "Beyond Prediction to Climate Modeling and Climate Control: New perspectives from the papers of Harry Wexler, 1945-1962." *The Development of Atmospheric General Circulation Models,* Leo Donner, Wayne Schubert, Richard Somerville, eds. (Cambridge University Press, 2011), 51-75; "Planetary-scale Field Work: Harry Wexler on the possibilities of ozone depletion and climate control." *Knowing Global Environments: New historical perspectives on the field sciences and the multiple scales of nature,* Jeremy Vetter, ed., (New Brunswick: Rutgers University Press,

“military” institutions, though they did in varying capacities support the US military, the USWB providing weather data and services and the NACA providing R&D support.

In the eyes of key Weather Bureau officials, the US meteorological community was in practice divided (and more importantly, uncoordinated) among Navy, Air Force, and Army Signal Corps research laboratories, their university contractors, and the US Weather Bureau proper. As these emerging technologies reached initial proof of concept phases, the Weather Bureau gradually accepted their eventual utility, but faced daunting barriers to entry. In the mid-1950s, the meteorological community weighed in on determinations over what observation equipment would be included on IGY satellites, but had marginal participation in development, operations, or data acquisition from the equipment. (See table 1.2 for a list of the relevant satellites).

From the perspective of the history of technology, this dissertation traces a seemingly linear path from 1940s sounding rocket programs to the mobilization of WWW resources in the mid-1960s. Table 1.2 posits a narrowing of vision necessary to “see” the gradual convergence of support systems, payloads, and expert knowledge into what would become NASA and the USWB’s TIROS satellite system. As such, this table emphasizes the continuities among seemingly distinct technical systems, filtering out most elements that were not adapted to TIROS.

2010), 190-211; “Earth Observations from Space: Accomplishments, challenges, and realities.” *NASA's First 50 Years: An Historical Perspective*, Steven J. Dick, ed., (Washington, DC: NASA, 2010), 543-562; “Polar and Global Meteorology in the Career of Harry Wexler, 1933-1962.” *Globalizing Polar Science: Reconsidering the International Polar and Geophysical Years*, Roger D. Launius, James Rodger Fleming, and David H. DeVorkin, eds(New York: Palgrave, 2010), 225-241.; and “Earth Observations from Space: The first two decades.” *Earth Observations from Space: The First 50 Years of Scientific Achievements* (Washington, DC: National Research Council, 2008.)

Table 1.2 TIROS Genealogy

(Instruments in boldface carried through to TIROS meteorological satellite system)

	Von Braun's ABMA Janus Recon. Satellite	Vanguard II Feb 1959 (IGY)	Explorer VI Apr 1959 (IGY)	Explorer VII (IGY)	ARPA Meteorological Satellite Plans 1958-59	NASA TIROS 1960+s[23]
Command and Data Acquisition		**Army Signal Corps**			**Army Signal Corps**	**Signal Corps on TIROS I and II, then Vanguard Division for Command and USWB for data acquisition**
Tracking		**MINITRACK** (developed from missile tracking equipment)	**Microlock and Minitrack**	**Microlock and Minitrack**	**Microlock**	**MINITRACK and improved MINITRACK system**
Suomi radiation budget				**Gross IR using flat plate radiometer**	**IR was removed due to budget cuts in 1959**	**Yes, TIROS III, IV, VII**
Stroud Infrared Instrument		Scanning IR was expanded for TIROS			**IR was removed due to budget cuts in 1959**	**Planned and cancelled for I and II, used on later models**
Launcher	Juno I, then planned II (derived from Jupiter and Sergeant missiles)	**Vanguard** (based on Viking and Aerobee-Hi sounding rockets developed for missile R&D)	**Thor Able** (2nd and 3rd stages from Vanguard)	Juno II	Juno II, then ARPA planned for launch on **Thor-Able-2**	Tiros II-X all **Thor Delta** (2nd and 3rd stages from Vanguard)
TV	**Chose .5" vidicon less power, less weight; RCA Camera**		TV, no evidence RCA, only 1 image, not clear enough to view clouds		**RCA Vidicon wide and narrow angle lenses**	**RCA Vidicon**
Stabilization, Bus	Janus I would tumble; Janus II have 4 weights	Vanguard sphere	"Paddle-wheel satellite" for solar cells			

[23] TIROS I and II were operated in collaboration with the DOD. See table 6.1 for details concerning TIROS satellites.

In many regards, the rocket and satellite R&D community had benefitted from a series of "surpluses" and windfalls. First Army Ordnance offered defense scientists and engineers a "free ride" of payload space on V-2 rockets. In years that followed, sounding rocket R&D so closely aligned with missile R&D, it created economies of scale and larger R&D projects in which scientific studies could be funded "in the margins" of more formal defense research contracts. Finally, the defense community of space science researchers enjoyed the windfall of both military and National Science Foundation (NSF) funding to support sounding rockets and scientific satellites in the International Geophysical Year.

The embedded-ness of these tools and researchers within defense centers in some regards constituted barriers to entry for the USWB. In time, this inaccessibility prompted a quickening in the civil sector. Weather Bureau officials soon became eager to not only keep abreast of DOD developments, but began pressing to exercise a coordinating power over activities they perceived as falling under the USWB's mandate to perform basic research in the upper atmospheric sciences.[24] Key USWB leadership expressed an abiding concern over the lack of coordination between military labs and the WB, indicating that because of the USWB mandate to perform basic research they ought to exercise some degree of jurisdiction over the performance of *all* US upper atmospheric research.

Between 1950 and 1960, the USWB officials struggled to operationalize this mandate. Housed within the Department of Commerce, the USWB had a reputation among the armed services and federal government for being grossly underfunded and its

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[24] See Chapters 3-5.

administrators (Reichelderfer and Wexler in particular) looked on with apprehension as they saw the armed service's influence on upper atmospheric research grow with increasing university funding, the (at least seeming) duplication of effort among the services, and the activities of projects and entire departments obscured by classification restrictions.[25] Beginning in 1956, the USWB would use connections at the National Academies of Sciences to begin circumventing the defense department's influence over basic R&D. Calling for an increase in "basic meteorological research" they began calling for a national institute for atmospheric research; 1958 brought the formation of the University Center for Atmospheric Research (UCAR) and 1960, the formation of the National Center for Atmospheric Research (NCAR).[26] While these were not the product of USWB or NAS politicking alone, they certainly helped reorganize non-military research along lines conducive to Reichelderfer's interest.

With July 1958 plans for the formation of a non-military space administration (NASA), USWB officials presumed that they would have full access to US meteorological satellite data, but 1958 brought more frustrations. Having failed to gain coordinating power over defense R&D in the basic atmospheric sciences or meteorological satellites, USWB officials pushed to fund a USWB weather satellite program *independent* of the DOD and failed.[27] In the days between the signing of the

[25] The USWB was transferred from the Department of Agriculture to the Department of Commerce in 1940.
[26] See Chapters Four and Five of this dissertation. Joseph Peter Bassi's dissertation does not address USWB interest but does document the formation and early years of the NCAR in *Creating a Scientific Peak: How Boulder, Colorado Became a World Center for Space and Atmospheric Science, 1945-1965.* See also the UCAR "Blue Book" available at http://www.ncar.ucar.edu/documents/bluebook1959.pdf.
[27] This deal was struck down by the Bureau of Budget due to the expectation that NASA would manage the US meteorological satellite system. See Chapter Five.

NASA Space Act and the actual operational opening of NASA, NASA officials to-be began negotiations with the DOD determining their division of labor. Initially they concluded that weather satellites would remain in in the Defense Department and undertook plans to have the Air Force Cambridge Research Center manage data from the US's first generation of meteorological satellites.[28]

Ultimately, the space science R&D community (embodied in part the newly acquired the Naval Research Lab-NASA Vanguard Division) converged with the US meteorological community, cooperating on the operation and data-handling of the Television Infrared Observation Satellite (TIROS). In 1962, this NASA-USWB partnership would begin coordinating for operational satellite capabilities central to the World Meteorological Organization World Weather Watch.

Historiography: (Re)Organizing for Space R&D, 1955-1959

This dissertation catalogs the emergence of meteorological satellite technologies from cornerstones of US national defense to tools of scientific development and cultural modernization. Under whose initiative were the first R&D satellites produced and with what aims in mind? Historians have detailed the manner in which the IGY Vanguard and Explorer R&D satellite programs came to be at once products and symbols of a cutthroat missile and space race.[29] Armed with the leftover hardware and know-how of German V-1 and V-2 rocket scientists, Soviets and Americans competed to be the first to launch a

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[28] See Chapter Five.
[29] Roger Launius, John Logsdon, Robert Smith, *Reconsidering Sputnik: Forty Years Since the Soviet Satellite,* (New York: Routledge, 2000), see in particular Michael Neufeld, "Orbiter, Overflight, and the First Satellite: New Light on the Vanguard Decision", Walter McDougall, …*The Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985), Constance McGlaughlin Green and Milton Lomask, *Project Vanguard* (Washington, D.C.: NASA SP-2009), Michael Neufeld, *Von Braun: Dreamer of Space | Engineer of War* (New York: Alfred Knopf, 2007).

satellite in orbit.[30] On August 2, 1955, President Eisenhower announced the US intention to launch at least one satellite for the International Geophysical Year. Later that same day, Leonid Sedov, of the Soviet Academy of Sciences announced the USSR's intent to orbit a satellite as well.[31] Two years later, on 4 October 1957, the Soviets succeeded in orbiting the first artificial earth satellite, Sputnik. Sputnik II followed just one month later. The successes of the Sputniks and the December setback of the US Vanguard test vehicle set forth a flood of Congressional and media inquiry. Investigations focused not simply on the ability of the US to launch a satellite, but the overall preparedness of satellite *and* missile programs. These investigations resulted ultimately in the backup Explorer program satellite launched 31 January 1958.

Rather than focus attention on orbiting hardware and rare launch dates, historian Walter McDougall has famously challenged this narrative, demonstrating that the US's painful opening of space race might be reinterpreted with an eye on the Eisenhower Administration's reconnaissance activities.[32] By publicly engaging the Soviets in a space

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[30] Siddiqi, *Sputnik and the Soviet Space Challenge.*

[31] Sedov chaired the one of two commissions concerning space. Whereas Anatoly Blagonravov headed the scientific commission on sounding rocket R&D, Sedov's commission had been established as a distinctly public forum in which Soviet scientists could discuss space exploration. See Siddiqi, *Sputnik and the Soviet Space Challenge,* 148.

[32] McDougall *The Heavens and the Earth*. For a fresh interpretation with more recent declassified sources, see Dwayne Day, "Cover Stories and Hidden Agendas: Early American Space and National Security Policy" in *Sputnik Reconsidered.* Also, L. Parker Temple III, *Shades of Gray: National Security and the Evolution of Space Reconnaissance,* (Virginia: AIAA Publishers, 2005). For further reading on the history of the US reconnaissance satellite program, see Paul B. Stares, *The Militarization of Space: US Policy 1945-84* (Ithaca: Cornell University Press, 1985), William E. Burrows, *Deep Black: Space Espionage and National Security* (New York: Random House, 1986), Dwayne Day, John Logsdon, Brian Latell, *Eye in the Sky: The Story of Corona Spy Satellites* (Washington, D.C.: Smithsonian Institute Press, 1998), Jeffrey Richelson,

race and doing so under the aegis of the UN's International Geophysical Year, Eisenhower and his intelligence apparatus side-stepped uncertainties regarding satellite overflight; namely, the question of whether or not sovereign airspace extended infinitely above each nation.[33] Through intensive analysis of the IGY, historian Rip Bulkely has written an institutional history illustrating in finer detail how the scientific programs of the IGY were often influenced by the US and Soviet national security states. Bulkely argues that US officials constructed a "superficially egalitarian programme of international scientific cooperation for the disproportionate benefit, much of it military, of their own country."[34] These and other analyses take as a given that the federal government was the foremost driver of scientific activities, directing research and distributing money as a near-monolithic entity.

Alan Needell's biography of Lloyd Berkner, *Science, Cold War, and The American State,* provides a more nuanced interpretation of the earliest days of spaceflight research from the perspective of one of the most influential scientific elites. Still focusing attention on the highest echelons of governance, Needell illustrates the rigorous debate, painful compromise, and at times tenuous coalition-building necessary to coordinate the resources of oftentimes unaligned government interests. Here, one individual's skills and

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America's Secret Eyes in Space: The US Keyhole Spy Satellite Program (New York: Harper and Rowe, 1990).

[33] More than once Soviet Premier Nikita Khrushchev had indicated that the United States lacked legal precedent to orbit satellites over the USSR. A careful reading of McDougall does not explicitly accuse Eisenhower of slowing the pace of Vanguard development, nor a conscientious denial of funds

[34] Bulkely, 102. See also Clark Miller, "Scientific Internationalism in American Foreign Policy: The Case for Meteorology: 1947-1958," *Changing the Atmosphere,* 167-181 and Roger Launius, "Toward the Poles: A Historiography of Scientific Exploration during the International Polar Years and the International Geophysical Year," *Globalizing Polar Science.*

values as “the public administrator, the manager, the technocrat, and the ‘statesman of science,’” played out, challenging the apparent dichotomy between “pure” knowledge-driven research and the necessity to secure patronage.[35] Rather than being disingenuous rhetoric and empty diplomatic posturing, the desires of these scientific communities for a well-managed international circulation of scientific knowledge were at once compatible with and necessary for Cold War national security.[36] Berkner carried significant influence in the IGY, both among the space scientists and the meteorological community.

Other high-ranking scientists’ and engineers’ careers illustrate the complex intersections of space policy, federal R&D policy, and statecraft. Influential policymakers and science advisers (including Vannevar Bush and James Killian) fostered abiding reservations about the practicability of guided missiles and satellites being as near to fruition as many DOD proponents would have them believe. G. Pascal Zachary’s biography of Vannevar Bush briefly addresses the “engineer of the American century’s” views on missile R&D, Sputnik, and the military potential of satellites, quoting Bush.[37]

Valerie Adams suggests that in the face of the increasing complexity of Cold War science and technology, President Eisenhower exhibited a unique tendency among US presidents in that he preferred to consult with civilians and “his scientists” on matters of

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[35] Needell, 364.

[36] Rip Bulkely *The Sputniks Crisis and Early United States Space Policy: A Critique of the Historiography of Space* (Bloomington: Indiana University Press, 1991), see also Needell, *Science, Cold War,* and Paul Edwards, “Meteorology as Infrastructural Globalism,” in *Global Power Knowledge: Science and Technology in International Affairs Osiris* 21.

[37] See the closing pages of Chapter Three. G. Pascal Zachary, *Endless Frontier: Vannevar Bush, Engineer of the American Century* (New York: The Free Press, 1997), endnotes 18-20 on page 481.

national defense.[38] Following the advice of the Technical Capabilities Panel and the PSAC, the Eisenhower White House was concerned only with the principle that the US launch a "scientific satellite." They left the scientific details to NAS committees and Department of Defense lab representatives.

To reiterate: neither meteorological satellites nor routine upper atmospheric research factored explicitly in executive policy *at this time*. Eisenhower overlooked them in part because satellites were unproven and emerging technologies. The US launch of scientific IGY satellites would permit initial testing and evaluation of such equipment, but he expressed no desire to provided for follow-on scientific satellite systems. Instead, plans for post-IGY meteorological satellites began to unfold at the armed services' level: in the Air Force, Army, and Navy, each to fill their own tactical needs. Having been granted the mandate to pursue reconnaissance satellites, the Air Force and later Army acquired the resources to coordinate experimental meteorological satellite systems as well.

Spaceborne cameras, telemetering equipment to radio information back to ground stations, as well as skills at photographic interpretation and rectification each overlapped considerably between reconnaissance satellites and meteorological satellites (commonly referred to as "weather reconnaissance" satellites). Economies of scale and even surpluses furthered the almost incidental development of meteorological satellites. When

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[38] Zuoyue Wang, *In Sputnik's Shadow: The President's Science Advisory Committee and Cold War America* (New Jersey: Rutgers University Press, 2008), James Killian, *Sputnik, Scientists, and Eisenhower: A Memoir of the First Special Assistant to the President for Science and Technology* (Cambridge, Mass: MIT Press, 1977), Valerie Adams, *Eisenhower's Fine Group of Fellows: Crafting a National Security Policy to Uphold the Great Equation* (Lanham: Lexington Books, 2006), Yanek Mieczkowski, *Eisenhower's Sputnik Moment; The Race for Space and World Prestige* (Ithaca: Cornell Univeristy Press, 2013).

RCA representatives lost the bid for the Air Force reconnaissance satellite program, they submitted an unsolicited proposal to the Army, which Wernher von Braun accepted. In 1958, the Defense Department determined that the US had no need for two photographic reconnaissance satellite programs and dubbed the Army's a weather reconnaissance satellite. Several histories have identified the defense origins of the TIROS weather satellite, but they all neglect explaining who—and appealing to what logic—actually drew the US's TIROS satellite plans from the Army to NASA.[39]

Told from the perspective of the space science communities and the meteorological community, this dissertation explores what organizational and technological progressions necessitated this transfer. Why were weather satellites a seemingly incidental outgrowth of DOD activities? Why, by 1958, were they utterly beyond the grasp of the Weather Bureau?

Between the launch of Sputnik and the October 1958 opening of NASA, bureaucratic groundwork was laid for the transfer of the Vanguard satellite team to NASA. This cross-section of space science talent included practitioners who developed scientific instruments, refined their use, sought research support, and kept abreast of International Scientific Union activity. Three authors of NASA history were themselves participants in the US's reorganization for space exploration between 1957 and 1960.[40] John Naugle, who used balloons and later sounding rockets to study photons and the

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[39] The Stroud team numbered five or six persons. Stroud campaigned actively to get NASA to transfer them against the wishes of the Signal Corps. Chapter 5.

[40] A fourth excellent memoir of this time is George Ludwig's *Opening Space Research: Dreams, Technology, and Scientific Discovery* (Washington, D.C.: American Geophysical Union Press, 2011). Ludwig worked with James van Allen.
Robert Smith focusing on one project but touches upon "scientific" origins of NASA

magnetosphere, transferred from private industry to take a research position at NASA in 1959. In his history of NASA's selection of space science experiments, Naugle is one of several authors who credit the Naval Research Laboratory Vanguard satellite team as being one of the two "heritages" of research culture transferred to NASA's Goddard Spaceflight Center.[41] Naugle's second "heritage" shaping Goddard—one-day home of the TIROS meteorological satellites—was the National Advisory Committee on Astronautics.[42]

Until the mid-1960s Goddard was the only NASA center conducting earth science.[43] While in Goddard's Office of Space Science, Naugle worked under Homer Newell. Newell (who transferred to NASA with the Naval Research Lab's Vanguard Project) was widely recognized by his peers as the "spark-plug" behind the formation of NASA in the guise it took (see appendices C and D for the COS proposal for a National

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[41] See John E. Naugle, *First Among Equals,* 46-48, Homer Newell, *Beyond the Atmosphere, Dreams, Hopes, Realities,* Alfred Rosenthal, *Venture into Space,* Linda Newman Ezell, *NASA Historical Data Book II,* and Howard E. McCurdy, *Inside NASA: High Technology and Organizational Change in the US Space Program* (Baltimore: Johns Hopkins University Press, 1993).

[42] Since 1915, NACA had been a center of aeronautical research, more a manifestation of the associative state than technocratic. The Committee had 17 members including officials from the DOD, Airf Force, naval aviation, Civil Aeronautics Authority, National Bureau of Standards, USWB, and the Smithsonian Institution along with non-governmental scientists and engineers. The Committee was authorized to perform research in labs placed under its direction, but also to contract out research to to encourage and support research in scientific and educational institutions. As of 1 October 1958, NACA would serve as organizational, facilities, and manpower foundation upon which NASA would be established.

[43] Heliophysics, aeronomy, cosmic ray studies, etc. all being distinct of planetary science, which was pursued at JPL. See Clayton Koppes, *JPL and the American Space Program: A History fo the Jet Propulsion Laboratory* (New Haven: Yale University Press, 1982).

Space Establishment).[44] Though their memoirs are extremely useful (and candid) insider reflections on the reorganization of space R&D and the operations of NASA, neither Naugle nor Newell offers perspective on the origins and transfer of the TIROS and few reflections on NASA's relations with the Weather Bureau. T. Keith Glennan, NASA's first Administrator kept a diary of his first year at NASA, but there, too, references to the transfer of TIROS are vague, likely due in part to the classified origins of the program and efforts of the Army to retain their weather satellite research team and infrared instruments.[45] Thus, space histories have only captured segments of an arc, from the sounding rocket origins to the IGY, or from IGY preparation to post-Sputnik damage control, or from the launch of TIROS to service in the UN's World Meteorological Organization World Weather Watch.

For a narrative to carry the histories of these research communities and Cold War technologies, it must span a number of coalitions (Table 1.1). Addressing the degrees of (un)coordination among this constellation of military and civilian institutions begs a new methodological approach. In his history of the Department of Energy Labs, Peter Westwick puts forth the vivid notion of "systemicity" to describe the competition, collaboration, specialization, decentralization, as well as inter- and intra-organizational dynamics. Westwick describes the national labs' systemicity, in language parallel to diverse and decentralized DOD labs, but also evoking their disconnect from the US Weather Bureau. Westwick observes:

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[44] See John D. Ruley, *The Professor on the Sixth Floor: Homer Newell, Jr. and the Developments of US Space Science*, BA Thesis Submitted to the Graduate Faculty of the University of North Dakota for MS, 2010, p. 116.
[45] Keith Glennan, *The Birth of NASA,* discusses TIROS in reference to the U-2 event.

> the national labs duplicated disciplines, machines, and missions and distributed them geographically. There had been several earlier proposals for a central research lab in the United States, most notably one spurred by the application of science to national priorities in WWI.[46]

While the centralized lab described by Westwick never came to fruition, the Army and the Navy did set up their own laboratories: the Army at Fort Monmouth, New Jersey (from which TIROS was transferred in 1959) and the Naval Research Lab in Washington, D.C. (from which the Vanguard space science team was transferred in 1958).[47] From its inception in 1947, the Air Force, too, began funding research in radio, sound, and optic wave propagation. Each armed service sought advancements in military communications, missile development, advanced warning systems, aircraft performance, electro-optical capabilities and the like. Each lab by policy or "in the margins" of applied research was also contributing to basic upper atmospheric research.

While the armed services funded several defense labs and university research contracts, they neither exercised nor sought an explicit systemic policy among the labs. Instead, collaborations such as those outlined in Table 1.1 came about for the most part organically from the labs' networked researchers. These successive coalitions and reorganizations (including the UARRP, the IGY, NASA, and the WWW) function as trading zones among developers of atmospheric instruments, users of these tools, managers of data, and users of data. Within the boundaries of basic or fundamental research, scientific researchers cleaved successive intellectual and bureaucratic "places" in which they might share observations and ultimately, collaborate with international

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[46] Peter J. Westwick, *The National Labs: Science in an American System* (Cambridge, Massachusetts: Harvard University Press, 2003), 308-309.
[47] See *The Genealogy of ARL* [Army Research Laboratory (ARL-P 360-2, 1997), available at www.DTIC.mil. See also Harold A. Zahl's memoirs *RADAR Spelled Backwards* (New York: Vantage Press, 1972).

partners. Thus, this dissertation traces the movement of resources from one extremely local field of knowledge production (national defense labs) to sustained use in NASA, the USWB, and ultimately, World Meteorological Organization partnerships. We will return to the notion of systemicity in Theme III, below.

Theme I: The Satellite System as Big Science

Rocket and satellite research exhibited many properties of a "Big Science," perhaps foremost among these was intra- and inter-national collaboration.[48] The German V-2 Project Paperclip team contributed mightily to the early days of US space science, providing insight about their past research and helping transform the V-2 missile system into a useful sounding rocket system.[49] Throughout the 1940s and 1950s, UARRP members remained active in International Scientific Unions and readily attended international symposia on upper atmospheric research. Sounding rocket researchers sought new geographic latitudes from which to launch their experiments, prompting international partnerships.

Between 1957 and 1958, the IGY initiated a trial period in which international partners could compare methods, share facilities, aid in satellite tracking, and share their

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[48] *Big Science* James H. Capshew and Karen A. Rader, "Big Science: Price to the Present," second series, *Osiris* 7 (1992), 23. Andrew J. Butrica, *To See the Unseen: A History of Planetary Radio Astronomy* (Washington, DC: NASA History office, 1996), ix. *Big Science: The Growth of Large Scale Research,* ed. Peter Gallison and Bruce Hevley (Stanford: Stanford University Press, 1992). Roger L. Geiger, "Science, Universities, and National Defense," second series, *Osiris* 7 (1992), 26-48, Patrick McCray, *Giant Telescopes: Astronomical Ambition and the Promise of Technology* (Cambridge: Harvard University Press, 2006).

[49] DeVorkin, Michael Neufeld, *The Rocket and the Reich: Peenemunde and the Coming of the Ballistic Missile Era* (Cambridge: Harvard University Press, 1995), see in particular the epilogue, "Peenemnde's Legacy."

interpretations of atmospheric observations. International collaborators tracked IGY satellites with Baker Nunn cameras, with ham radios, and agreed to the US Army Corps of Engineers constructing Minitrack stations in their countries. The international Minitrack network used to track and predict the orbit of IGY satellites was itself a collection of enormous scientific instruments with antenna systems stretching 500- and 700-feet. Fourteen Minitrack stations together composed a north-south "fence" across North, Central and South America.

Another attribute of big science was that satellites and sounding rockets were extremely *expensive.* Each pass of a satellite over the Minitrack network was estimated to cost $10,000 to $20,000 (not adjusted dollars).[50] When, in 1960, the Weather Bureau at last began tooling up to fund an operational meteorological satellite system, the $500M appropriated for the cheaper model meteorological satellites dwarfed the $50M laid aside for traditional USWB functions. Yesterday and today launch services typically dominate the cost of developing and building remote sensing systems.

Inherent to the expense of these sounding rocket and satellite systems were high rates of failure, particularly in the early years. Managers soon learned to order multiple spare parts for quality control purposes and build multiple spare satellites in anticipation of design flaws, launch failures, and improper orbital insertion. Redundancy increased the effectiveness of these systems, but also the price. See Table 2.1 for an illustration of the many shades of failure encountered in Viking sounding rocket launch. When, in 1958-9 NASA negotiated the transfer of the ailing meteorological satellite program out of the DOD, its funding included five complete models of the TIROS satellite: two engineering

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[50] Shirley Thomas, *Satellite Tracking Facilities* (New York: Holt, Rinehart and Winston, 1963), 24.

prototypes and three flight models (with two as backups in case of launch or orbital insertion failures).[51] For further illustration of the high launch vehicle failure rate in the early years of the US space program, see Table 6.2 for details concerning the Defense Meteorological Satellite Program 1962-1965.

Table 1.3 US Launch Record: Successes and Failures[52]

Year	Successes	Failures	Percent Success
1957	0	1	0
1958	7	10	41
1959	11	8	58
1960	16	13	55
1961	29	12	71
1962	52	7	88
1963	38	8	83
1964	57	7	89
1965	63	7	90

Rocket and satellite research were also *expansive* in nature. Its practitioners pressed rocket engineering to higher and higher altitudes. Dissatisfied with the sounding rocket's brief glimpses of the upper atmosphere, they conducted studies determining the fiscal and technical demands of launching instruments high enough to attain earth orbit. International Geophysical Year scientists put forth the notion that a scientific satellite was but a "Long Play Rocket" and commonly used the abbreviation "LPR" to identify the NAS committee responsible for satellite development and coordination. This play on words was intended to illustrate the continuities between sounding rocket research and

[51] Abe Silverstein to Hugh Vest, 16 June 1960, Project TIROS Record Number 6467, NASA Historical Records Center (hereafter NHRC).
[52] Table from George H. Ludwig, *Opening Space Research,* 80.

satellite-based research. Often a satellite is described as a platform launched with enough velocity that it is constantly "falling" around the Earth.[53] Having had a sample of the observations satellites could perform in the IGY, the space and meteorological science communities sought the experimental TIROS meteorological satellite systems. Following that, the military and civilian meteorological communities' expectations rose again, desiring 12-month a year *operational* coverage in an *operational* satellite system.[54]

Teamwork was another important facet of satellite research as Big Science. Even the legendary Wernher von Braun, the talented rocket engineer who became a leading figure in human spaceflight exploration is remembered, not simply for his profound individual technical capabilities, but as an astute manager and a gifted proselytizer to superiors and staff alike. Chapters Two through Five detail the maturation of a team of space scientists and engineers who together transitioned from early V-2 sounding rocket research to the Viking sounding rocket, Vanguard launch vehicle and Vanguard satellite, and finally, adoption of the TIROS meteorological satellite. Managers and engineers Milton Rosen, John Hagen, Homer Newell, and John Townsend were all key figures of this team, collaborating with researchers who had developed instruments for flight on their rockets and then satellites.

This work was also interdisciplinary in nature. David DeVorkin has illustrated the diversity of sciences and engineering contributing to the formation of the US space sciences between 1945 and 1955. This dissertation sheds light on the careers of others

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[53] This is how satellite orbits are explained in the National Air and Space Museum gallery "How Things Fly." The earth's gravitational pull keeps "pulling" the satellite. This is true only of low earth orbit. Geostationary satellites (not covered in this dissertation) are at a point of equilibrium between the earth's gravity and the satellite's velocity.

[54] Constant satellite coverage was achieved beginning with TIROS IX, the experimental model for the TOS, (TIROS Operational System.)

including Milton Rosen, the radio engineer turned rocket engineer, John Mengel, who worked on infrared detection and later designed the Minitrack (radio) tracking stations, and Herbert Friedman, the x-ray physicist who retooled himself from refining quartz crystal quality control to becoming a world leader in solar research using sounding rockets, balloons, and satellites.

Theme II: Basic Research and the Space Sciences

Historians of science and technology have illustrated that it is nearly impossible to draw clear and universal distinctions between the activities of fundamental knowledge-driven research and the development of applications. In doing so, some authors direct our attention to "in service engineering" and concurrence, demonstrating that often developing an application necessitates backtracking into scientific study or that major developments can take place without understanding the scientific principles on which they operate.[55] Other critics commonly identify these presumed ideal types as the basis of the much-maligned "linear model." In the linear model of research, policy is made based on the presumption that innovation begins with basic research, then progresses to applied research, development, and ends with production and diffusion to users.[56] Historian David Edgerton has asserted that criticisms of the linear model are themselves oversimplifications. The linear model was never intended to be an analytically useful

[55] See in particular Phil Scranton, "Urgency, Uncertainty, and Innovation: Building jet engines in postwar America," *Management and Organizational History* 1 (May 2006), pp. 127-157.
[56] Quote from Godin "The Linear Model of Innovation: The Historical Construction of an Analytical Framework" see also Bruno LaTour on diffusion in *Science in Action: How to Follow Scientists and Engineers through Society* (Cambridge: Harvard University Press, 1987).

concept, rather exists solely as a "foil for the more elaborated academic account," little more than "a classic straw man."[57]

In tracing the institutions and individuals facilitating the convergence of missile and reconnaissance technologies into a meteorological satellite system, I opt not to problematize the scattered conceptions of what constitute basic/fundamental/scientific/research or application/engineering/development. Instead, this dissertation sheds light on the utility of the notion of basic research as an instrument of organizational reform and institutional autonomy. At the individual level, the act of classifying research as lacking or conversely *being free from* immediate application indicated the logic by which patronage may be supplied or denied. Thus, to sponsor research explicitly ordained as "basic" was to sanction intellectual latitude, but also express a degree of faith, either in the promise of the researcher or the field of study, or both.

At an institutional level, the notion of basic or fundamental research functions as an instrument of (re)organization. It helps practitioners and administrators distinguish knowledge production from scientific operations/applications such as weather

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[57] David Edgerton, "'The Linear Model' did not exist: Reflections on the history and historiography of science and research in industry in the twentieth century" in *Science-Industry Nexus* (New York: Watson, 2004) Significantly, Edgerton indicates that one of the first uses of the term "linear model" was to describe the dauntingly complex couplings between basic scientific research and "technological solution." As early as a 1969 *Science* article, the linear model was identified by that name and defined as a model in which "innovation seems to be a rational process, essentially similar to the other, more systematic functions of an organization." The article's authors, executive director of the US Air Force Office of Scientific Research and a vice president in industry, stated that innovation is very much "irrational" and impossible to "be programmed in advance," but suggest institutional mechanisms for exposing technologists to new scientific knowledge. William J. Price and Lawrence W. Bass, "Scientific research and the innovative process: The dialogue between science and technology plays an important, but usually nonlinear role in innovation," *Science* 164 (1969), pp. 802–6.

forecasting. In the case of NASA's formation, it was an important but unclear boundary between the military (tactical and strategic applications) jurisdiction and NASA (basic research and civilian applications). At first, these boundaries justified leaving R&D meteorological reconnaissance satellites in the Department of Defense. Later, when NASA and USWB officials negotiated their division of labor on satellites, it was agreed that NASA would function as the R&D institution developing successful weather satellite instruments and systems, but that the USWB as user would fund *operational* weather satellites. More than once the plasticity of such inter-related and overlapping binaries (such as basic/applied, military/non-military, R&D/operational, etc.) provided ground for conflict and renegotiation among the armed services labs, US Weather Bureau Representatives, and NASA representatives.

Of the three armed services functioning as the origins of the space sciences, the US Navy held a long-standing reputation for funding a greater proportion of exploratory basic research than the others.[58] However as defense and R&D budgets at the close of the Korean War, it became harder to justify new research projects to sponsors outside the Naval Research Lab.[59] Classification of work as being "basic research" could be problematic when dealing with sponsors other than the Office of Naval Research, such as the Bureau of Aeronautics or the Bureau of Ordnance. Milton Rosen, chief designer of the Viking sounding rocket recalled that finding support for basic research beyond the NRL was "unfruitful" specifically because "Viking [sounding rocket] was viewed as an

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[58] DeVorkin underscores the move that NRL made 1945+ to build more basic research divisions and sections. See also Harvey Sapolsky's *Science and the Navy: the History of the Office of Naval Research* (Princeton: Princeton University Press, 1990).
[59] Detailed in Chapter Four.

upper air research vehicle and not as a weapon."[60] In the words of William Kellogg, head of RAND's Geophysics Engineering Division, the formation of a National Space Establishment would "Allow a long term program of space research to be carried out *without interference with or by the military requirements for missiles*, etc."[61]

Throughout this narrative, researchers, engineers, meteorologists, and a host of science policymakers invoke the notion of basic research to classify relationships of patronage, to describe research objectives, to define institutional mission, and to justify international collaboration. They gesture toward a spectrum spanning idealized poles with knowledge-driven research on one end and applications-oriented development on the other. They use a range of actor terms to communicate this notion. Following the Second World War, researchers commented that they had not had time while pursuing wartime crash engineering projects for the scientific "systematic study" of newly recognized radio phenomena. When Army Ordnance invited defense and university labs to launch scientific instruments on V-2 rocket firings, Col. James B. Bain distinguished between Ordnance's interest in applications and the researcher's field of studies, stating that Ordnance was primarily interested in "the rocket itself" but was glad to contribute to the scientists' "research program" by providing payload space for the instruments. The IGY Technical Panel on Earth Satellites and Panel on Instrumentation referred to "the quest for knowledge about our solar system" and a "scientific program" when advising on the "basic research objectives of a continuing program in satellite research." Such a

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[60] "Inquiry Into Satellite and Missile Programs Hearings Before the Preparedness Investigating Subcommittee of the Armed Services 85th Congress November 25, 1957 - January 23, 1958 (Washington, D.C. US Government Printing Office, 1958), 2095. Hereafter "Satellite and Missile Programs Hearings."
[61] Ibid, emphasis added, 2118.

program would demand innovative techniques and hardware: "techniques for the recovery of packages from a satellite," satellite instruments to measure photons, ionospheric activity, micrometeorites, and geomagnetic fields.[62] President Eisenhower referred to the "the expansion of human knowledge" when recommending the organization for a NASA and indicating that its basic research would make available "discoveries of military value" which would be applied to "activities peculiar to or primarily associated with military weapons systems or military operations."[63]

While the NRL may or may not have been the most amenable home for basic research in the armed services, the mid-1950s brought brutal cuts to funding: 10% across the board for the armed services, all forced to reduce R&D expenditures. As will become evident in Chapters Three and Four, upper atmospheric rocket and satellite research, widely recognized as one of the most expensive fields of R&D, had reached an existential crisis by the opening of the International Geophysical Year. The precarious state of the nascent space sciences in the mid-1950s casts new light on the formation of NASA. NASA was widely recognized as a centralization and reorganization of resources intended to match and ultimately beat the Soviet lead in the space race. From the perspective of a handful of scientific researchers, NASA was also an institutional "homeland" providing a mandate for *sustained* basic research and international

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[62] The IGY Technical Panel on Earth Satellite Program (NAS), the Working Group on Internal Instrumentation, the Working Group on Tracking and Computation, and the Working Group on Satellite Ionospheric Measurements published their proposal (based on William Kellogg's proposal prepared for the WG on Internal Instrumentation) was published in *Science* 127 (11 April 1958), pp. 793-802.
[63] President's message dates to 3 April 1958. Quoted in *Science* 127 (18 April 1958), pp. 864-865.

collaboration following several years of incremental funding from the Defense Department and the temporary support for IGY scientific satellites.

Though the instruments and systems were coming together at this time, meteorological satellites did not factor prominently in national policy. Chapters Three through Six shift focus from the UARRP to inter-organizational relations among the Weather Bureau, the UARRP, NASA, and individual defense labs. At the institutional level, characterization of research activities as being basic science defined institutional missions and more than once leveraged calls for the formation or re-organization institutions. Theme three, below, elaborates on how more than once the USWB referenced their mandate to perform basic atmospheric research for the US government as justification for their coordinating military, university, and USWB research.

Theme III: Military and Civil | National and International

> …space exploration has not only been a project of national consideration but also the result of communities (or individuals) who identify with a whole host of other markers that are not connected to national claims… [highlighting communities] is a way to problematize the notion that space exploration represents national aspirations.[64]

Before TIROS could "get to the global" its predecessor systems (Vanguard, Explorer, and sundry sounding rocket exercises) had to be ushered through critical and uncertain moments in R&D policymaking. At each of these moments state and/or military mandate were tweaked. Perhaps at times outright undermined. What ideolog(ies) ushered TIROS from the national to the global? The seemingly parochial world of scientific practice reified its norms in these six institutional steps. In the interest of

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[64] Asif A. Siddiqi, "Competing Technologies, National(ist) Narratives, and Universal Claims. Toward a Global History of Space Exploration," *Technology and Culture* 51:2 (April 2010), 425–443, at 425, 439.

pursuing fundamental knowledge, basic research, environmental data and other avatars of "openness" and communality Lloyd Berkner, Homer Newell, Francis Reichelderfer, Harry Wexler, and their colleagues wielded these very principals of openness and basic research as instruments of federal reorganization (illustrated in Table 1.1).

As noted above, historians of science and technology have thoroughly deconstructed the linear model as well as the murky distinctions between what constitutes basic and applied research. This dissertation uses the notions of fundamental and applied as less a definition between epistemic activities and more an instrument of organizational power. In the chapters that follow, we will see how Reichelderfer, Newell, et al. cast broad organizational nets of "basic research" to help build the largest possible Cold War era coalitions (the UARRP, IGY, NASA, NCAR, WWW). Often, they were motivated by a desire to keep funding for civilian research on par with the armed services. In rare events, they actually coordinated military and civil activities as one.

It is important to note that for decades, USWB's Francis Reichelderfer had facilitated coordination and even coalitions among the armed services and USWB. As a navy aerologist, aviator, and balloonist, Reichelderfer had traveled to Europe where he learned the Norwegian frontal forecasting method. The Bjerknes School of meteorology had been developed during World War I restrictions on the broadcast of weather forecasts and synoptic observations.[65] While many other national weather services adopted his methods, the USWB did not. Following his studies in Europe, Reichelderfer wrote a

[65] See Williams 72-75, Nebeker, and Robert Marc Friedman, *Appropriating the Weather; Vilhelm Bjerknes and the Construction of a Modern Meteorology* (Ithaca: Cornell University Press, 1989).

report and later technical manual guiding application of the Norwegian method to forecasting. This manual facilitated the adoption of these methods by the USWB, armed services, commercial airlines, and other industries. Reichelderfer also took an active interest in the training of a knowledgeable base of aerologists and aerographers for wartime service. Throughout the Second World War, Reichelderfer created committees to coordinate the activities of USWB, Civilian Aeronautics Authority, War, and Navy Departments.

Internationally, Reichelderfer was widely accepted as one of the leading powerhouses behind IMO-WMO reorganization and wholly supportive of Harry Wexler's machinations for the formation of a WWW. Thus, his record in coordinating the US armed services, universities, USWB, National Academies of Sciences, and ultimately contributing to the formation of the US NCAR, speak to aims of national and international organization.

Reichelderfer took great pride in his wartime service and accepted the wartime restrictions to the sharing of weather data as a reasonable matter of course. And yet one decade before Eisenhower named the military-industrial-complex, he cautioned of the undue influence of military research and development funds upon the atmospheric sciences. In private correspondence Reichelderfer observed that, "With the prolonged period of military expansion and military funds available for all manner of research and development, there have been evidences of more or less permanent plans by the military to invade the civil meteorological field." This, he believed, resulted in "a growing tendency for other agencies to assume leadership in meteorological service developments and in meteorological research."[66] Reading between the lines, Reichelderfer and his staff were as vexed by what the armed services had as the limited resources the Weather Bureau could secure. Being tucked away under the Department of Commerce, the Weather Bureau remained notoriously underfunded.

Reichelderfer did not seek compartmentalization between military and civilian (an impossibility) nor reductions in military research *per se*. Reichelderfer sought to re-establish the Weather Bureau's statutory role with a "new and *comprehensive* program in meteorology."[67] Thus, he hearkened to principals of efficiency that would in turn improve productivity. In 1946, Vannevar Bush had adopted a similar stance. Bush, as former head of the Office of Scientific Research and Development in WWII, had been asked to report to President Roosevelt on the best possible governance of science in the postwar years. Regarding the necessity to declassify wartime scientific discoveries, Bush suggested that this would result in a more effective management of R&D resources and would function to "relieve the military services of unnecessary civil duties and to eliminate wasteful duplication."[68] On one hand *Science, the Endless Frontier* was a daring call for sustained federal support of the basic sciences; on the other hand, it was a nuanced study articulating methods for the *reasonable* demobilization of WWII R&D.

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[66] Reichelderfer to Wexler, August 13, 1951, "New Approach to General Coordination of Meteorological Research Sponsored by the Government" Box 5, General Correspondence Folder 1951, Harry Wexler Papers, Manuscript Division, Library of Congress, Washington, DC (Hereafter Wexler Papers).
[67] Emphasis added.
[68] Bush addressed the need to declassify war research under the headings "Security Restrictions Should be Lifted Promptly" and "Need for Coordination" in Chapter 5, The Problem of Scientific Reconversion. Vannevar Bush, *Science: The Endless Frontier,* (Washington, D.C.: Government Printing Office (GPO), 1945), 23.

Years later, Reichelderfer expressed precisely the same sentiment in nearly the exact same words—that the movement of basic research from the military would "relieve" the armed services of unnecessary civilian duties. Reichelderfer was not so much perturbed by defense labs performing basic research in "his field" as the fact that he could not match, much less manage it. Invoking the Weather Bureau's mandate to perform "basic research" (his own words repeatedly), Reichelderfer sought to increase access to data and fundamental data produced beyond USWB. Without suggesting explicitly that persons or research programs be removed from or denied the DOD, he and colleagues in the National Academies of Sciences cast a broad net of "basic upper atmospheric research" and called for its coordination (read: centralization) in a *National* Center for Atmospheric Research. Unable and perhaps unwilling to breech the military labs, he sought to (re)appropriate the mandate of basic research. The principal of a centralized *national* organization resonated with the Eisenhower Administration's desires to maintain an economical government, innovative defense base, and civilian regulation of the armed services. It did so with the formation of NCAR and it did so with the formation of NASA.

Reichelderfer's efforts paralleled those of the RSRP community. As they cleaved manpower, facilities, and intellectual property from the armed services, encouraging their transfer to NASA, they did so hearkening to openness as a means to more effective national governance *and international governance*. Getting to the global, when we expand our focus to the international coordination of meteorological resources, the communality of basic science and data (as its raw material) was again routinely invoked as an organizing principal to secure domestic and international buy-in. There can be no doubt that when Reichelderfer, the first World Meteorological Organization president, pressed for the USWB's role of TIROS data agent that he did so with the aim of contributing to the WMO.

Theme IV: Units of Analysis

In tracing the genealogy of a technical system (Table 1.2) through and among multiple institutions, I have benefitted from the guidance of historians suggesting possible methods for thinking about the Cold War, US R&D, and space history.

David Hounshell has suggested that in rethinking science and technology in the Cold War, historians be "much more rigorous" in selecting units of analysis. Allowing that no unit would be universally optimal, he suggested that ample studies have been performed of individual scientists as a way to analyze motivations, allegiances, and compromise. Instead, he coaxes his readers to explore the utility of scientific institutions, scientific disciplines, scientific organizations (military and non-military), and even artifacts themselves in better explaining the relationship of the Cold War state to science.[69] To varying degrees, this dissertation makes use of these units. It is an extension of David DeVorkin's history of space science into the age of satellites and NASA's formation. It discusses the careers of individuals who labored to contribute to national R&D institutions while improving their professional standing in international scientific unions and contributing other professional societies. And, while there is limited analysis of the technology proper, it traces the movement of a technical system among a number of R&D to operational scientific institutions (ultimately the USWB and WMO).

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[69] David Hounshell, "Rethinking the Cold War; Rethinking Science and Technology in the Cold War; Rethinking the Social Study of Science and Technology" *Social Studies of Science* 31 (2001), 291-292.

The resulting division of labor among these disbursed developers of TIROS instruments demands a trans-organizational scope. Westwick's notion of systemicity mentioned above is tremendously useful in analyzing this constellation of institutions, not operating in isolation, but not thoroughly coordinated in policy. They were at times collaborating, at times competing. Returning to the notion of using basic research as an instrument for defining organizational mission or bringing about a reorganization of resources, this sense of systemicity may be used to explain the aspirations of several individuals. Some sought to impose a more effective order upon basic research in the upper atmospheric sciences (Reichelderfer, Wexler). Others may have desired a sustainable order for the conduct of space sciences (Newell, Kellogg) or an order for the most efficient development of missile and satellite technologies in the face of Soviet belligerence (Lyndon Johnson, Wernher von Braun). Some even used NASA's unique mission as an expression of US commitment to space for "peaceful uses" (as expressed later in the career of Eilene Galloway). This study looks to the logic behind these organizational divisions of labor and how those logics facilitated (or forestalled) the resulting World Weather Watch.

Is it possible to sift through these fragmented aims and identify a larger trend at work? More than a decade ago, historian of the Global Cold War, Odd Arne Westad prompted us to think more critically about the different cultural settings and political purposes for which technology was developed in the US and Soviet Union. To say that linkages between strategic priorities and socio-economic development were fundamentally tied was, for both Superpowers, nearly self-evident given the longevity, the breadth, and the sheer power commanded by the two Cold War cultural complexes.

Driving these military-industrial-complexes were, at least at times, harmonious ideologies among science practitioners and statecraft.

Westad defined ideologies as "a set of fundamental concepts *systematically expressed* by a large group of individuals.[70] The 1958 Space Act, with all its problematic and strategic ambiguities, was just such an expression. Faced with the finite nature of the IGY, contradictory calls for a space spectaculars, an accelerated military space program, a peaceful national space program, and even UN-regulated transnational space program, the Eisenhower administration and Congress opted for the formation of National Aeronautics and Space Administration, transferring the IGY satellite systems and operators to NACA.[71]

This transfer represented a dramatic disjuncture in policy history, paralleling the Atomic Energy Commission's founding.[72] The transfer of the Army Corps of Engineers' Manhattan Project to the AEC was an important expression of postwar US ideologies. This transfer of resources balanced a distinct postwar faith in science advancing social and military development with the presumption that these research activities were best managed under civilian auspices.[73] The transfer of the Manhattan Project and formation

[70] Emphasis added, Odd Arne Westad, "Bernath Lecture: The New International History of the Cold War: Three (Possible) Paradigms," *Diplomatic History* 24:4 (2000), 551-565.
[71] The fact that it was an administration and not an agency speaks to the power that it was expected to wield, likely *vis a vis* the Army Ballistic Missile *Agency* and the Advanced Research Projects *Agency*. See Chapter Four and Logsdon, *Legislative Origins.* It was not until 1960 that the ABMA was transferred to NASA.
[72] So far as missile capabilities were pursued largely as vehicles for nuclear weapons, this history is a continuation of the US's development of atomic weapons systems.
[73] See Rodney Carlisle, *Management of the US Navy Research and Development Centers During the Cold War* (Navy Laboratory/Center Coordinating Group Naval Historical Center: Washington, D.C., 1996), Richard Hewlett and Oscar E. Anderson Jr., *The New World (1936-1946),* Richard G. Hewlett and Francis Duncan, *Atomic Shield, 1947-1952* (University Park: Pennsylvania State University Press, 1969), George T. Mazuzan and J.

of the AEC are important formative policy experiences in the decades leading up to NASA, making NASA's formation a point divergence itself. Unlike atomic energy, space was not centralized into one organization, but NASA was formed to *coordinate* overlapping interests among multiple military, civilian, academic, and private sector R&D centers.

With NASA as well as the AEC, there were palpable tensions between national priorities and national security. These themes are evident in the much-contested New Look strategy, the carefully staged post-Sputnik missile and satellite preparedness hearings, and in Eisenhower's farewell address.[74] Throughout, Eisenhower sought to temper the growth of a national security state, protect long-term economic stability, and offer neither too generous nor too parsimonious expressions of support to Western bloc allies. In light of these conflicting interests, the formation of NASA was in some regards a compromise ("for my scientists")[75] going against his administration's concerns over duplicative R&D efforts and the push for the privatization of American R&D.[76]

Ultimately, the NASA reorganization amounted to a re-crafted projection of power—domestically and abroad. On one hand is the well-documented and far better

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Samuel Walker, *Controlling the Atom: The Beginnings of Nuclear Regulation, 1946-1962* (1985).

[74] On New Look (representative of his early policy) see Robert R. Bowie and Richard H. Immerman *Waging Peace: How Eisenhower Shaped an Enduring Cold War Strategy* (Oxford: Oxford University Press, 1998), Iwan Morgan, *Eisenhower Versus the Spenders* (London: Pinter Publishers, 1990), Ira Chernus *Eisenhower's Atoms for Peace* (College Station: Texas A&M, 2002).

[75] Regarding Eisenhower's change of heart regarding duplicative military and civilian space centers of research see Z. Wang, 93-97 , Killian, "my scientists" 239, regarding space agency proposals from the ARS, TPES, etc, see 124-5.

[76] Eisenhower had to be talked into centering space R&D in a civilian institution, detailed by Walter McDougall and in my Chapter Four. Hoover panel cited in *Management of US Navy R&D Centers.*

publicized projection of American dynamism in the 1957-1969 space race and 1961-1969 moon race. On the other hand is a more subtle expression of international leadership, mandated explicitly in the 1958 Space Act and with collaborative autonomy exceeding the AEC. With logic paralleling the Atoms for Peace program, carefully measured intercourses of technological know-how and scientific resources were used to advance scientific knowledge, but at the same time to grasp a position of leadership in international policymaking. Here, scientific practice mated neatly with statecraft that was evolving away from the intractability of Eisenhower's New Look.

To borrow from John Krige, in getting to the global this dissertation "interrogates the sources of technological change, the social conditions that produced it, the factors that induce technological dynamism." As such, it explores a set of fundamental concepts expressed by a series of US scientific communities (see the coalitions and their hearkening to basic research Table 1.1). [77] Without a substantive *national* policy, could there be a viable *international* policy?

Chapter Summaries

This dissertation is arranged chronologically with each chapter detailing one phase or shift in US R&D organization. These include the Upper Atmospheric Rocket Research Panel, the International Geophysical Year, the National Aeronautics and Space Administration, the transfer of the TIROS Satellite to NASA and the formation of the National Center for Atmospheric Research, and last, the World Weather Watch.

[77] Krige, speaking on Westad's Bernath lecture, "Contribution to Panel 57, Roundtable: Technology and US Foreign Relations," SHAFR Annual Meeting, Alexandria, VA, June 23-25, 2011.

Chapter Two "Going the Sounding Rocket Route: Foreshadowings of Satellite R&D 1946-1951" illustrates how far removed the Weather Bureau was from rocket and satellite R&D. Researchers funded by the armed services (in DOD labs, universities, and private firms) were able to pair missile R&D with upper atmospheric research, often conducting basic research in the margins of missile development projects. They coordinated resources in the Upper Atmospheric Rocket Research Panel and speculated on satellite flight, finding it far too expensive to warrant investment by the armed services.

In Chapter Three, "The Promise and the Threats of Emerging Satellite Technologies: UARRP and NAS Coordination for IGY Satellites 1950-1957," the Eisenhower Administration offered a subsidy to UARRP research communities that they might launch a scientific satellite in the 1957-1958 International Geophysical Year. In coordinating for the Vanguard IGY satellites, researchers working through the National Academies of Sciences set policy precedents for incremental, scientific satellite programs. Working with international partners, they established an order for launch notification, aid in tracking satellites, and for sharing data. The Soviet Sputnik preceded the Vanguard satellite into space. Following a Vanguard test vehicle failure in December 1957, Congress, the White House, and the US public engaged in an eight-month debate over how to reorganize space R&D. During this time, a number of "space stunts and spectaculars" were offered as balm to the US's prestige, but threatening the US's legitimacy as a scientific and "peaceful purposes" space power.

Chapter Four, "Seeking Sustainable Resources and US Leadership in Space: NASA's Formation November 1957-April 1958" illustrates that due to cutbacks in defense research and development, UARRP members faced an uncertain future in sounding rocketry. This was a critical moment shaping the Janus-like facade of US Cold War power. After much negotiation among the White House and Congress (both consulting often with the scientific communities) the 1958 Space Act charged NASA with planning and conducting aeronautical and space activities, providing the widest practical dissemination (meaning for military, civilian, and international users) of information of its activities and results, and charged with international cooperation.[78] However throughout this time the proposed TIROS meteorological satellite remained under the aegis of the DOD's Advanced Research Project Agency and not the USWB or NASA.

Chapter Five is "Coordination for Meteorological Satellite R&D: 'The USWB is About to Enter the Space Age.'" As of the summer and fall of 1958, ambiguities surrounding NASA's formation and its role coordinating military and non-military resources led to a plan with ARPA for the DOD to launch the US's first generation of R&D weather satellites. More disconcerting to the USWB, all satellite images and data would be routed through the Air Force Geophysics Research Division, with the Weather Bureau receiving limited data second-hand from the DOD. USWB perceived this as an incursion of DOD research institutions into the WB's basic research mandate. After a brief period uncertainty and intervention by the Executive branch, the Weather Bureau was established as NASA's "meteorological agent" thereby securing responsibility for

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[78] Arnold Frutkin, *International Cooperation in Space* (Englewood Cliffs: Prentice-Hall, 1965). See also John Logsdon, *Legislative Origins of the National Aeronautics and Space Act of 1958*: *Proceedings of an Oral History Workshop Conducted April 3, 1992* (NASA Monographs in Aerospace History Number 8, 1998), and Roger Launius, (ed) *Organizing for the Use of Space: Historical Perspectives on a Persistent Issue* (AAS History Series Volume 18 (San Diego: American Astronomical Society, 1995).

data-handling. TIROS was transferred to NASA in the spring of 1959 and launched a year later.

Chapter Six “Going Operational: Bilateral Cold Line; Multilateral World Weather Watch,” illustrates how USWB researchers took a bilateral mandate for sharing satellite data and laid foundation for a global weather observation system of unprecedented scope. As with the IGY and formation of NASA, USWB officials invoked, constructed, and reified norms of scientific internationalism even as they mobilized new and otherwise inaccessible resources to support US hard power.

Given my institutional affiliation, it is useful to consider one last methodological note: Why NRL? For one, this lab’s research divisions provide a useful case study of the nature of policies and day-to-day practice of defense labs in the mid-twentieth century. Among the many actors participating in the V-2 Panel, UARRP, IGY, NASA formation, and WWW, it is useful to trace the careers of a handful of people through formative moments in the history of US R&D. Actors from the NRL-Vanguard team who carry this story from beginning to end include Homer Newell, John Hagen, and Milton Rosen. Second, NRL provides a broad sampling of the sciences and engineering necessary for space exploration, a budding vertical monopoly from launch design through to data reduction and the publication of scientific papers, which leads to the third and perhaps most important factor. NRL UARRP researchers who peopled the Vanguard Division and then transferred to NASA provide a direct lineage from the V-2 Panel to TIROS operation.

In sum, this is as much about the military communities of researchers as it is the USWB community. The military researchers spent years investing in subsystems and techniques they knew would yield operational weather satellite systems for tactical use. Due to a confluence of congressional, White House, space science community (UARRP then NASA), and USWB interests, these subsystems were gradually ushered from military to temporarily international and finally operationally global (WWW) networks.

CHAPTER 2
Foreshadowings of Satellite R&D:
"Going the Sounding Rocket Route," 1946-1951

Introduction

> In the space imagination, nations typically represent airtight constituencies despite evidence to the contrary that *communities* cutting across borders and cultures…represent important actors and actions…In the rush to draw up airtight national narratives, we inevitably tend to gloss over the ambiguities and flows among each of these communities.
>
> Asif Siddiqi[79]

During the Second World War, US defense labs began work on a wide variety of missile systems, developing knowledge bases in propulsion, missile tracking, and missile guidance that would one-day support satellite launch and operation. Thus, more than a decade before space exploration became a national priority (with the launch of Sputnik in 1957), a variety of scientific communities struggled to master the scientific sounding rocket system, intending to one day design satellite systems. Beginning in 1945, these research communities adaptively reused missile hardware, collaborating on a number of upper atmospheric research projects. Using *rocketsonde*—at times missiles without explosive warheads, at times rockets specially designed for scientific research—they captured elusive snapshots of the upper atmosphere and the ionosphere. Having established that their basic scientific research could remain unclassified, they shared their findings at national and international conferences, published in scientific journals, and circulated in unclassified research reports.

In defense labs, postwar "surpluses" of equipment, German V-2 prisoners of war, and US missile experts willing to practice science "in the margins" of more formal R&D

[79] Emphasis original. Siddiqi, "Competing Technologies, National(ist) Narratives," 438.

projects fostered a *de facto* monopoly over US sounding rocket as scientific instrument. Gradually, other scientific communities came to accept the validity of the V-2 Panel researchers rocket observations.[80] The late 1940s and first couple years of the 1950s featured three concurrent developments important for understanding the technical and policy history of weather satellites. (1) Leading US Weather Bureau researchers and administrators became intrigued by the use of upper air photographs to map cloud formations for synoptic weather prediction and studying interactions between land and air masses. (2) V-2 Upper Atmospheric Research Panel members devised a variety of techniques to sound the upper atmosphere for temperature, pressure, and density, slowly reaching a consensus on the calibration and refinement of their instruments as well as drawing up tables for pressure, densities, and temperature of the upper atmosphere. (3) Geophysical research communities in other countries (and the UK in particular) expressed an interest in coordinating observations of upper atmospheric phenomena in the earliest years of International Geophysical Year coordination and planning.

During this time, US Weather Bureau Chief Francis Reichelderfer voiced reservations about the tendency of other institutions to assume leadership in meteorological research and began positioning his bureau to "take a much broader role in planning and coordinating research."[81]

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[80] Devorkin, *Science with a Vengeance.*
[81] Francis Reichelderfer to Harry Wexler, August 13, 1951, "New Approach to General Coordination of Meteorological Research Sponsored by the Government." Weather Bureau concerns centered on numerical forecasting, the WBAN service, and basic research taking place at defense labs (See final subsection of this chapter). Box 5, File General Correspondence 1951, Wexler Papers.

Operation Paperclip

Throughout the course of the Second World War, US Army and Navy research labs labored to keep abreast of German guided missile developments. From captured hardware, they developed radio-jamming countermeasures as battlefield stopgaps and compared US and German methods of design and operation. At the close of the War, Army and Navy commissions traveled to Germany to study missile guidance technologies, attempting to glean information regarding engineering and operations. Ernst Krause, from the Naval Research Laboratory's Communications Security Section expressed particular interest in inertial systems, gyro drift rates, and the general accuracy of German missiles. The V-2, *Vergeltungswaffe* "Vengeance Weapon" was just one object of interest.

In the chaos of postwar Germany, the V-2's primary designer, Wernher von Braun approached Major General Walter Dornberger about the possibility of surrendering to the US. The two agreed that it was indeed time "to put our baby [the V-2] in the right hands." Von Braun had been planning the defection for some time, telling an old friend and radio operator that he would need his assistance when, fairly soon, he hoped to fly to the moon, presumably for the US.[82] Missile designers and hardware brought from Germany in this, Operation Paperclip, were key drivers igniting US interest in sounding rockets and possible satellite programs. Exposure to German rocket scientists and von

[82] Michael J. Neufeld, *Von Braun: Dreamer of Space | Engineer of War*, (New York: Alfred A. Knopf, 2007), 198-200.

Braun's enthusiastic prognostications in particular legitimated the notion that satellites might soon become viable instrument—and weapons—platforms.[83]

To von Braun, the so-called "dreamer of space," applications such as sounding rockets and scientific satellites were nearly mundane distractions from his grander aims of human spaceflight and interplanetary exploration. However in the US, the charismatic rocket designer came in contact with a number of research communities with very different objectives and philosophies for space exploration. For these US researchers, the Earth's upper atmosphere might also have been characterized as a "frontier"—less because space was uninhabited by humans and more because it was very much *uncharted* from an electromagnetic perspective.

Since the early 1900s, US radio researchers had studied the properties of the upper atmosphere and beyond that, the ionosphere, attempting to render communications technologies and radio reconnaissance techniques more reliable, but at the same time remain a step ahead of potential adversaries in radio countermeasures. Some studied aerology, generally accepted as a synonym for meteorology, but with emphasis on meteorological research and not forecasting. Aerologists studied the free atmosphere above 20 meters using aircraft, balloons, and rockets. At heights these platforms could not reach, radio propagation or fading was used to analyze the physical and electromagnetic changes of the earth's atmosphere. Aeronomists, studied the upper regions of the earth's atmosphere where ionization, dissociation, and sundry chemical

[83] See Chapter 5 of David DeVorkin, *Science with a Vengeance: How the Military Created the US Space Sciences After World War II,* (New York: Springer-Verlag, 1992), 59-72.

reactions that among other things, produced a "skip distance" effect on high frequency radio waves.

The scientific communities von Braun's team came in contact with were laboring to secure sponsorship for research beyond the atmosphere. They tended to focus their studies on radio propagation, optical sciences, guided missile research, radio astronomy, remote sensing, reconnaissance, astrophysics, and spacecraft engineering. For them, human spaceflight was but a distant possibility.

In the winter of 1945-46, the US Army Ordnance (which had taken possession of the Operation Paperclip team and hardware) offered scientific researchers at select institutions access to the V-2s. Originally, the Army intended for approximately five of twenty-five V-2s to be offered for scientific payloads. Proposals were due to the Army in a mere eleven days. On 16 January, twelve institutions offered proposals for upper atmospheric research and applications development projects. Army Ordnance quickly reached the decision that *all* V-2s would be used for research and that an organizing panel of scientists was necessary to keep launches and their payloads in order.

At the first V-2 Panel meeting, Col. James B. Bain, the Army's coordinator of interservice activities explained that there were three major "Categories of Interest" surrounding the V-2. These included "Military interest in the rocket itself" (trajectory, handling, firing, detection), Countermeasures, and last, "Meteorology Physics of the Upper Atmosphere."[84] Army Ordnance was interested in upper atmospheric research only

[84] Represented at the meeting were the Army Signal Corps, National Advisory Committee on Aeronautics, University of Michigan, Army Wright Field (aircraft radio lab), General Electric, Army Air Force, Naval Research Lab, Princeton University,

"to the extent of the effect of the upper atmosphere on the flight of missiles." Thus, while Ordnance was "glad to contribute to the research program" by flying instrumented payloads provided by the research institutions, they had limited interest in the coordination of scientific research.

From the opening days of the Panel, Army representatives took a relatively hands off approach in directing scientific use of the V-2s. Col. James Bain had initially hoped for General Electric to lead the researchers, however the firm proved unable. In January of 1946, Naval Research Lab's Ernst Krause moved to establish some degree of latitude over the program. Already at odds with Johns Hopkins' Applied Physics Laboratory over the question of which lab would coordinate Navy's program in physics and the upper atmosphere, (APL had been designated as such by the Navy Bureau of Ordnance and NRL the lead by the Navy's Office of Research and Inventions—the predecessor to the Office of Naval Research), Krause sought to establish NRL's position as lead. Warheads, minus their explosive payloads, became platforms for affixing instruments such as cameras, spectrometers, and photographic plates attempting to capture the sun's x-ray emissions.[85]

Throughout January, Krause quickly assumed a leadership role on the Panel, stepping in to offer 10-channel telemetry equipment when GE could not provide the 30-channel telemetry systems they had originally offered and arguing that the Panel ought to have a strong centralized coordinating responsibility for determining what equipment

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Applied Physics Lab, Harvard, Army Signal Corps Lab. V-2 Report No. 2, meeting date 27 March 1946, Box 34 file Upper Atmosphere Rocket Research Panel, Wexler Papers.

[85] Devorkin, 63-4.

would be flown for experiments.[86] By February, Krause and his Lab were perceived to be appropriate leaders for the V-2 Panel, given the NRL's growing stake in the upper atmospheric sciences. Meeting notes indicated that Krause was all but a shoe-in as chairperson, "inasumuch as Dr. Krause is devoting 100% of his time to the physics of the upper atmosphere, he was the logical candidate." There were no dissenting votes.[87]

In addition to the NRL, over time as many as twenty-five institutions contributed resources, expertise, facilities, and manpower to the Panel. In some cases, areas of specialization led to divisions of labor: General Electric provided ground crew support for launches; Harold Zahl of the Army Signal Corps Research Laboratory offered to make available to all partners all his information on batteries intended to operate in zero atmosphere. [88] In other cases, the research centers devised "competing" means to tackle the same problem and compared notes. Tracking methods ranged from Doppler, to Theodolite, and Beacon. Instruments that weathered V-2 flight awaited utterly catastrophic "landings." Intact, the missile achieved terminal velocity of 2000 miles per

[86] DeVorkin, 63.
[87] V-2 Report No. 1, meeting date 27 February 1946, Box 34 file Upper Atmosphere Rocket Research Panel, Harry Wexler Papers, Manuscript Division, Library of Congress, Washington, DC.
[88] Radio propagation research was an important driver behind upper atmospheric studies. This lab operated under several name changes while performing research for the Army Signal Corps in radio communications and upper atmospheric research (among other projects, the Signal Corps developed meteorological instruments for the Army.) Between 1917 and 1962 it was Signal Corps Radio Laboratory at Fort Vail, Fort Monmouth Radio Lab, Signal Corps Laboratories (SCL), relocated to Camp Evans nearby, becoming the Evans Signal Laboratory (ESL), postwar it was Signal Corps Engineering Lab (SCEL), and in 1962 it became the home of the Army Electronics Command. See "The Genealogy of ARL (Army Research Laboratory)" ARL-SP 360-2 available at www.DTIC.mil. The author refers to them as the Army Signal Corps Lab for continuity.

an hour, meaning, “most of the vehicle was pulverized beyond recognition.”[89] Later, rocket teams affixed explosives to the rocket body with the knowledge that two or three less aerodynamic segments would return to earth more gently, a mere “several hundred feet per second.”

This coordinating panel formed a loose confederation of research institutions—each was allocated its own V-2 warheads for instrumenting as it saw fit, though they routinely used the Panel as a forum to avoid unnecessarily duplicative experiments or to compare notes on instrument design and results. From the outset, the Naval Research Laboratory and the APL procured the bulk of services and hardware. The University of Michigan (funded by the Air Force after its 1947 establishment), the Ballistic Research Laboratory, the Army Signal Corps Research Laboratory (ASRL), Princeton, and the Air Force’s Cambridge Field Station (later AFCRC/AFCRL), were also members (see Appendices A and B for membership over time). The US Weather Bureau’s Harry Wexler attended meetings as an observer, but not actually representing the USWB. Instead, Wexler attended as the chair of the NACA’s Special Subcommittee on the Upper Atmosphere.

Given the fact that “basic research” was the primary aim of the Panel, from its beginning, Col. H. Toftoy had established that V-2 firing schedules, basic elements of rocket design, and flight information would be unclassified. This was significant because these engineering details were necessary for interpreting measurements taken by scientific instruments. Rocket design and details of its flight offered clues into the interpretation of atmospheric observations. One example was that aerodynamic pressure

[89] Rosen and Snodgrass, 6.

curves were necessary to calculate atmospheric density from pressure measurements along the surface of the rocket. Thus, critics might argue that when researchers published observations in journals or shared them at conferences, they were offering glimpses into the operations and capabilities of US rockets and missiles.

This policy remained in place in spite of occasional efforts by the armed services to classify data. NRL mathematician Homer Newell explained: "The panel unanimously agreed to fight classification, citing the importance of the scientific process, in particular open publication and free exchange of information, to a basic research activity." He continued, stating that, "while there was something to be gained by classifying certain specific uses of scientific information, there was much to be lost by classifying the purely scientific data."[90]

Vanguard's Birthplace 1945-1946: "The Things that Were Available"

Why were NRL and Krause in a position to take a leading role in the Panel? Months before the Army Ordnance's invitation to collaborate on the V-2 Rocket Research Panel, NRL managers had been reorganizing their institution to function as a leader in upper atmospheric rocket research. In his reflections on postwar planning at the Homer Newell illustrated the uncertainties and the excitement of that time.

> All of us were talking about the future….One day the subject of using the experience that we had gained in designing television-guided missiles be used to investigate the upper atmosphere was proposed by Milt Rosen. That was thought to be a great idea. We immediately began to think of many ways in which it would be important to the Navy and to the military in general, and so we

[90] Homer Newell, *Beyond the Atmosphere: Early Years of Space Science* (Washington, D.C.: NASA SP-4211, 1980), 42-43. Newell cites Col. H. N. Toftoy to Commanding General, White Sands Proving Ground, in Megerian, minutes of panel, rpt. 13, 29 Dec. 1947. Homer Newell was a leading figure in UARRP and IGY, before finishing his career as NASA Associate Administrator.

> concluded that the military ought to support work of that sort…Most of us found the idea of rocket upper air research so attractive that we stayed.[91]

Through 1945 and the opening of 1946, proponents of sounding rocket research worked to establish the immediate utility and long-term value of upper atmospheric—and even orbital—observations. In October and November of 1945, the Navy Bureau of Aeronautics' Committee for Evaluating the Feasibility of Space Rocketry submitted recommendations for an Earth-orbiting "space ship" designed for research and weighing approximately one ton.[92] Exploratory contracts soon estimated that such a venture could cost far more than feasible. Newell recalled, that he and his colleagues were "seriously considering the possibility of using satellites." However, "we hoped that we would be able to take things that were available and just use them. We couldn't do that, and we couldn't get money to build things on our own, so we went the sounding rocket route."[93] Thus, as of 1946, the "things that were available" at NRL were insufficient to justify a satellite program. Sponsors were unwilling to fund anything beyond studies of satellites, certainly not the hardware.[94]

Rocket soundings of the upper atmosphere did prove feasible. Explicitly contrasting their policy with WWII "crash programs," NRLers decided to adopt an

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[91] Interview of Dr. Homer Newell by Dr. Richard Hirsh on 17 July 1980, Archives for the History of Quantum Physics Collection, Niels Bohr Library and Archives, American Institute of Physics, College Park, MD USA (hereafter AIP Collection), http://www.aip.org/history/ohilist/4795_1.html.

[92] Constance McLaughlin Green and Milton Lomask, *Vanguard: A History* (Washington, D.C.: NASA SP-4202), 6-7.

[93] Interview of Dr. Homer Newell by Dr. Richard Hirsh on 17 July 1980, AIP Collection, http://www.aip.org/history/ohilist/4795_1.html

[94] NRL's primary sponsors included the Bureau of Aeronautics, Bureau of Ships, Bureau of Ordnance, which had been contracting with the lab for R&D since immediately after its earliest years of formation. Later came the Office of Research and Inventions was reorganized into the Office of Naval Research.

incremental approach to R&D: they would begin with rocket soundings of the upper atmosphere and in time, pursue orbital capabilities. The technical complexity and financial risks of "going the sounding rocket route" were mitigated by investment in guided missile research. By the end of the Second World War the Lab had an established reputation in the field of rocket research and had built a number of partnerships with private firms producing rocket bodies and a host of radioelectronics. The testing and development of guided missiles demanded that they be able to telemeter data, but also be tracked by interferometry on the ground.[95]

To develop this hardware indigenously, the lab reorganized. At that time, the lab acquired a new Captain, H. A. Schade, who had been Head of the US Technical Mission to Europe. Hoyt Taylor, a radio physicist at NRL recalled that Schade intended to reorder all Lab research into:

> . . . a complete and integrated program for the Laboratory as a whole, a program which would lay more emphasis on basic research and less emphasis on problems of a transitory interest. Also, he stated that research must return to the hands of the civilian scientists and that the military dominance of the divisions, which had become progressively noticeable during the war, must be removed.[96]

Krause and Schade were eager to retool the NRL for more intensive guided missile research, expanding on expertise in both engineering and science, in part to retain scientific talent that may otherwise leave at the end of the war. Throughout the course of the war effort, lab workers had placed more basic scientific enquiry or projects lacking

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[95] With time, the phase comparison guidance system for ballistic missiles would become a central element to NRL's Vanguard and later NASA's earth science satellite programs. The "Minitrack" network would span first the American continents and then expand to meet the needs of later generation satellites. See May 1952 studies on use of phase comparison guidance, 6628 LEK 3/13/6 Folder Vanguard Chronology 1945-57, RN 6600, NHRC.
[96] "The First 25 Years of the Naval Research Laboratory," (Washington, D.C.: NAVEXOS P-549), 71.

immediate application on administrative back burners and several had voiced the desire to return to more basic research. Harold Dinger, of the ship-shore communication division, explained that in wartime "factors affecting the accuracy of radio noise meters had been noted, but little effort could be spared for systematic study."[97] However, he explained that immediately after the war researchers went to work on the problem, both in his lab and at the University of Pennsylvania. Many anticipated a return to more basic research pursuits following their wartime activities. X-ray physicist Herbert Friedman designed instruments for detecting radiation (radiacs), used x-ray diffraction to analyze the quality of quartz crystals being used in aircraft radios, and developed an improved gas tank gauge for B-17s. Postwar, he used sounding rockets to research properties of the upper atmosphere, ionosphere, and solar rays. Radio Physicist John Hagen, who would direct the Vanguard program at NRL and later NASA, spent the war working on radar and ultra-high frequency communication. Radio engineer Milton Rosen, chief designer of the Viking rocket and Vanguard launch vehicle, worked on radio and radar missile guidance during the war. John Mengel, who would design Vanguard's satellite tracking network, had spent the war as a radio engineer at General Electric and later the Bureau of Ships, working in infrared detection and installation on ships.[98]

The sentiment of a postwar return to basic research was not at all particular to the NRL. Noting that the ratio of expenditures on applied to basic research had risen steadily since the 1930s, Vannevar Bush, head of the Office of Scientific Research and

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[97] Harold E. Dinger, "Radio Frequency Interference Measurements and Standards," *Proceedings of the IRE* (Institute of Radio Engineers) (May 1962), pp. 1312-1316.

[98] Record Number 002707, Folder "Background Summaries of NASA Top Staff," NHRC.

Development, proclaimed in 1946, "We have been living off our fat [of fundamental knowledge]. For more than 5 years our scientists have been fighting the war…diverted to a greater extent than is generally appreciated from the search for answers to fundamental problems."[99] Later, a State Department study expressed a similar sentiment that, "technological advancements of the last war…appear to have drawn substantially on the potentialities of latent basic knowledge with almost no augmentation [of basic scientific knowledge]." "The technological development of really new industries is dependent upon the acquisition of new knowledge."[100]

The urgency and the largesse of the war effort left labs with not only expanded facilities, a wide selection of researchers, and captured equipment from adversaries to spur further scientific and engineering research. As indicated by Dinger, these years focused on engineering and field use had exposed a variety of vexing (or alternatively promising) avenues of scientific research. While the dichotomy of basic and applied research has been thoroughly deconstructed by historians and sociologists alike, the researchers' collective and individual perceptions of work as "basic" or "applied" functioned as important markers for identifying themselves, articulating the relevance of their work, and the degree to which it could be circulated as unclassified, restricted, or

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[99] When Bush problematized the US's lapse in basic research, he did so advocating increased spending on colleges and universities "to meet the rapidly increasing demands of industry and Government for new scientific knowledge." Bush's Report to Roosevelt at once praised the US for its successful mobilization for WWII and called for a responsible postwar demobilization (titled "A Problem of Scientific Reconversion"). Vannevar Bush, *Science: the Endless Frontier.* (Washington, D.C.: Government Printing Office, 1945), pp. 22-23. See David Edgerton "'The Linear Model' did not exist: Reflections on the history and historiography of science and research in industry in the twentieth century" in Karl Grandin and Nina Wormbs (eds), *The Science-Industry Nexus: History, Policy, Implications* (New York: Watson, 2004).

[100] Ibid, 27.

fully classified. Milton Rosen explained in somewhat rosy terms: "Some of our men were trained as physicists—in spectroscopy, in nucleonics, in ionization. To meet the demands of war they had worked as engineers. But now the prospects for peace were bright—now, if ever, was the time to do basic research."[101] In the context of defense labs, the prospects of performing basic research were not just that it was perceived as more "academic" or "pure," (perceptions openly fostered in the interest of recruiting promising researchers from universities or other federal labs). Basic research carried an appeal also because it communicated an autonomy if not an expression of trust between sponsor and the chosen researcher.

Looking back on the NRL's relationship to one of its main sponsors, the Office of Naval Research, one Captain praised the ONR as an agency that helped "represent this …Laboratory and protect its integrity and independence."[102] As part of this gesture of confidence in the researcher, basic research was permitted in the "margins" of more formal, more applied research projects on the understanding that the central deliverable would still be met. Looking back three decades after his participation in the V-2 Panel Upper Atmospheric Research Panel, Herbert Friedman recalled "The Bureau of Ships was very generous with us, because we had produced all of these radiation instruments for the Navy radiac program." In the immediate postwar years, he recalled that they, "were very indifferent to our sloughing off substantial amounts of money to do anything we please, and in fact, looked at it as kind of subsidizing research which might benefit

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[101] Milton Rosen, *The Viking Rocket Story* (New York: Harper & Brothers, 1955), 19.
[102] *Report of NRL Progress July 1973* (Washington, D.C.: Naval Research Lab, 1973), 90. He also attributes Commadore Schade, "who undoubtedly negotiated that independence, who structured a coherent Laboratory out of the monstrosity which had grown to satisfy wartime needs…"

them down the road."[103] Similarly, physicist James van Allen, who had helped develop the radio proximity fuse at APL in the Second World War, wrote to a colleague in 1946: "I have no apologies whatever for working on investigations of no foreseeable application; but such a project will not divert any appreciable effort from our present program, since such evaluations will be essential by-products."[104] In this spirit, lab researchers and administrators pursued research into the properties of the ionosphere, cosmic rays, and solar physics not chasing after conceptions of "pure" knowledge for knowledge's sake, but confident that these explorations would at some unpredictable point in time reinforce military's more applied knowledge base in launching missiles and rockets.[105]

X-ray physicist Herbert Friedman offered his interpretation of the director of research's policy, indicating that the lab would acquire the most competent researchers possible and "let them do whatever they want to do, and we feel certain we'll get a payoff." These forays into fundamental science were conducted ever on the presumption that down the road new scientific instruments such as sounding rockets promised to further the design of military applications. These included the development of reliable guidance systems, the detection of high-altitude craft and missiles, the development of countermeasures, and some even suggested the remote detection of nuclear explosions.[106]

Dealing essentially with unknown unknowns, research administrators and sponsors vested a degree of autonomy in defense-funded scientific researchers. Operating

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[103] Interview of Dr. Herbert Friedman by Dr. Richard Hirsh on 21 August, 1980, AIP Collection, http://www.aip.org/history/ohilist/4613.html
[104] Devorkin, 202. APL is described by DeVorkin as a "warborn" institution dedicated to the development of guided missiles.
[105] DeVorkin, 78.
[106] Homer Newell (ed), *Sounding Rockets* (New York: McGraw-Hill, 1959), 45.

at the epistemic edge, such researchers were often granted intellectual and managerial autonomies on the faith that they would identify the next viable course of development. Homer Newell, who over the course of his careers at NRL and NASA would author many books and reports about or outlining the effectiveness of basic scientific research characterized these as "uncommitted researchers," explaining they, by definition "cannot point to the future and say that his researches will produce this or that specific application as a payoff." Instead, basic research as Newell characterized it, demanded a more permissive organizational structure. He defined it as "nonprogrammatic" or "nonmission" meaning in the margins of formal research programs and projects, "nonapplied," meaning not yet contributing to a material application and therefore harder to judge as effective or not.[107] While the pressures to eventually produce useful applications or to identify new fields of research were undoubtedly high, collectively, these actor terms express expectations of intellectual and bureaucratic flexibilities and latitude they deemed necessary for institutionalized creativity.

Particularly after the close of the Second World War, lab managers made it a policy to encourage the publication of NRL research in scientific journals, in the romanticized words of one of the lab's best-known physicists, "participation in the brotherhood of science has had the fortunate effect of greatly augmenting NRL's reputation as an institution devoted to basic as well as military research."[108] Professional advancement of their researchers augmented the prestige of the institution, both of which would increase the lab's standing in the eyes of potential job applicants or potential research sponsors.

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[107] Beyond the Atmosphere, 18-19.
[108] Quoting A. Hoyt Taylor. NAVEXOS P-549, 74.

The wind down of war mobilization and the perception of the Lab's rightful return to more basic scientific inquiry are important also because they provide organizational context for Krause's assertive behavior in the V-2 Panel formation. In the fall of 1945, Krause began working with department and section heads of the Lab, to restructure research at the NRL to better accommodate the institution's growing stake in guided missile technology *and* upper atmospheric science. By mid-December, 1945, NRL superintendents had established the Rocket-Sonde Research Section and expanded the Guided Missiles Research Program.

V-2 Upper Atmospheric Research Collaboration & NRL Leadership

> . . . we had a tremendous fund of knowledge gleaned not only from our own experience, but also from almost every domestic and foreign missile project.[109]

While unusually well-coordinated and unusually large in nature, coordination on the V-2 Panel was not a complete anathema to defense research communities. R&D is an act of institutional coordination from an idea's inception, to proposal, funding, research, development, and, when applicable, production in industry. For the Army and the Navy, the vagaries of radio operation (from low to high frequencies) led to calls for centralized labs in the First World War. While the Army Signal Corps conducted radio research in Evans, New Jersey as early as 1917, the Navy failed to centralized radio research until the 1923 formation of the Naval Research Laboratory.

Before and after the inception of these centralize research facilities, engineers and radio physicists at defense labs stayed networked in professional societies such as the Institute of Radio Engineers (IRE, later IEEE) and the International Radio Science Union

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[109] Rosen, *Viking*, 18.

(URSI). Presenting at conferences and publishing papers was not only a means to hone professional credentials, but also a way to stay abreast of developments in partner labs and industry. Oftentimes, when beginning a new R&D project, researchers would visit institutions engaged in related research to exchange ideas and tour facilities. These professional connections facilitated transfers of expert knowledge, necessary to stay abreast—if not ahead of—competition and collaborators in the US and abroad.

Howard Lorenzen, referred to often as the "Father of Electronic Warfare," recognized the necessity of these reciprocal partnerships. Arriving at the NRL in 1940 and retiring in 1973, his career in electronic countermeasures rode the arc of American security regimes from World War Two through much of the Cold War. In spite of this, he asserted, "There's no question about it…We had a policy from the very beginning. If you had a visitor show him what you're doing. I mean, none of the 'hold it in the back room and if somebody came from the Signal Corps Lab, well fine, bring them in and show them the works.'" Drawing important distinctions, he explained, "Unless somebody else said, 'This is so damned classified you can't show it to anybody.'" Otherwise, providing someone was from within the defense community, visitors would receive a tour of facilities in which "the guy that was working on it would tell you exactly what he was doing."[110]

Lorenzen's observations and the implication that the Army Signal Corps Lab was viewed as a constant research partner to NRL provide an instructive foreshadowing.[111]

[110] Howard Lorenzen Interview, Oral History Files, NRL History Office.
[111] From 1946 through the 1961, the Army Signals Corps Research Lab would continue to be a critical partner to NRL. Continuing a collegial relationship dating to the 1920s, the labs worked together on the V-2 Research Panel, the IGY's Vanguard satellite system, the Army Ballistic Missile Agency's Explorer, and finally when NRL's

Despite the fact that the defense labs frequency competed for resources, recognition as the originator of techniques, acknowledgement as rightful patent holders, and the like, they did commonly compare notes and even share facilities such as the White Sands Proving Ground Army Ordnance Test Station with one another.

In 1946 and 1947, the V-2 Panel proved a useful mechanism for coordinating research projects, setting ground rules for Panel activities, and the general professionalization of an emerging community of space scientists. In July of 1946, the Panel arranged division of labor along four lines: Ballistic measurements (by the Ballistic Research Lab, Aberdeen Proving Ground); Missile Behavior (General Electric as coordinating agency, NRL telemetering group); Detection and Warning (Army Signal Corps coordinating, Army Ground Forces, Army Air Forces); Physics of the Upper Atmosphere (NRL coordinating agency, APL, Princeton, University of Michigan, Air Material Command, Wright Field).[112] The Panel agreed upon radio frequency allocation, distributed procedures and news regarding preparing warheads for launch, compared notes on equipment performance, and reported on methods of instrument recovery after V-2 launches.

V-2 Panel proceedings have been reported as "unclassified," however distribution statements on reports and related documents and details of minutes indicate that V-2 participants still produced research and reports under classification restrictions. At the

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Vanguard team transferred to NASA's Goddard Spaceflight Center, they collaborated with the ASRL, keeping TIROS weather satellites I and II operating. William Stroud and a few other key ASRL researchers would petition NASA management to transfer them to NASA against Army wishes, covered in Chapter Five.

112 H. N. Toftoy to Commanding Officer, White Sands Proving Ground, "Responsibilities and Coordination of V-2 Firing Tests" 10 June 1946, Box 34, File Upper Atmosphere Rocket Research Panel, Wexler Papers.

second meeting, Col. Bain reported that classification of the missiles would remain restricted "until the public showing," though groups could enact higher classification restrictions as necessary. To this, Krause went so far as to assert that "everything at NRL is unclassified" but specific documents dealing with "certain classified equipment" would be marked and classified accordingly. Later that year, Krause submitted an article to the classified publication, *Guided Missile Magazine*. Remarking that each agency was responsible for handling its own publicity, he did advise that they avoid giving the impression that one agency was doing all the work.[113]

Such networking was tremendously important for this group honing new skills for exploring the upper atmosphere and attempting to gain credibility in pre-existing fields of science. Fred Whipple, a Harvard researcher contracting for the Navy Bureau of Ordnance, proved a valued asset, being a member of the Joint Research and Development Board (promoting Army and Navy R&D) and member of several geophysical panels. In the summer of 1947, Whipple suggested that the Panel begin considering whether to associate themselves more with the American Physical Society or the American Association for the Advancement of Sciences.[114]

Throughout these years, the defense labs also maintained active international contacts in International Scientific Unions such as the International Radio Science Union (URSI). US military representation in the URSI included the Army Signal Corps Research Lab, the Naval Research Lab, the Air Force's Wright Air Development Center,

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[113] V-2 Report #4 Minutes of the V-2 Upper Atmosphere Panel Meeting, 3 June, 1946. Box 34, File Upper Atmosphere Rocket Research Panel, Wexler Papers.
[114] V-2 Report # 10 Minuts of the V-2 Upper Atmosphere Research Panel Meeting 7 May 1947. Box 34, File Upper Atmosphere Rocket Research Panel, Wexler Papers.

the Navy Electronics Laboratory, the Ballistic Research Laboratory, the Atmospheric Ionization Laboratory of the Air Force Cambridge Research Laboratory, Air Force Geophysics Research Directorate, and the Applied Physics Laboratory. Representatives from these institutions contributed to deliberations on policy, such as radio frequency allocation, radio measurement, and standards. They also participated in scientific commissions such as radio astronomy, terrestrial radio noise, ionospheric radio propagation. While intelligence gathering was certainly one element in these interactions, its important to remember that lab recruitment policies quite candidly acknowledged the necessity for the labs to support and *produce* reputable contributions to the basic sciences.[115]

Indigenous Rockets to Replace the V-2

Over the years, Operation Paperclip engineers remained on call for consultation, but minutes give no indication that they attended Panel meetings in any formal capacity. Rarely were they referenced by name, rather, minutes in the early years indicated: "German calculations indicate skin temperature…"[116] "the Germans had fired 2 V-2 missiles vertically with empty warheads…"[117] "the Germans are working on a recovery device…", and the like. At their 12 November 1946 meeting, the Panel voted to continue

[115] The USWB was also represented at URSI. See Report to the National Research Council USA National Committee of URSI on the XIth General Assembly of URSI August 23-September 3, 1954.
[116] V-2 Report # 1 Minutes of the V-2 Upper Atmosphere Panel Meeting, 27 February 1946. Box 34, File Upper Atmosphere Rocket Research Panel, Wexler Papers.
[117] V-2 Report #2 Minutes of the V-2 Upper Atmosphere Panel Meeting 2 April 1946. Box 34, File Upper Atmosphere Rocket Research Panel, Wexler Papers.

using V-2s beyond the original twenty-five (Army-offered) firings "because of its merit and present relatively low cost."[118]

As UARRP researchers approached the end of their "surplus" payload space on V-2s, they began to discuss arrangements for coordinating post-V-2 research. Before the invitation from the Army to use V-2s, most of these institutions had been planning to design sounding rockets to meet their specific needs. The Army-JPL WAC-Corporal was furthest along in development, designed specifically for upper air research, it had a limited payload-altitude performance. The WAC had been available for use even when the US Army Ordnance Corps offered to make available a large number of captured V-2 rockets.[119] Throughout 1945, several WAC Corporals were fired, carrying instruments over 200,000 feet (nearly 38 miles). The V-2 Panel reported that the WAC was useful for temperature and pressure readings, "but [was] not the same class with a V-2," achieving lower altitudes and with a maximum payload capacity of only ten pounds (whereas a V-2 could lift more than 1,000 pounds).[120]

That same year, the Navy Bureau of Ordnance partnered with APL developing a more affordable mid-altitude alternative. Named for Aerojet Engineering Corporation and its relationship to the Bumblebee family of APL missiles, the Aerobee sounding rocket wound up capable of carrying its payload as much as 80 miles aloft, with an average altitude of 47 miles.[121] While the NRL did contribute to the Aerobee design (and later

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[118] V-2 Report #7 Meeting 4 November, 1946. Box 34, File Upper Atmosphere Rocket Research Panel, Wexler Papers.
[119] Homer Newell (ed), *Sounding Rockets* (New York: McGraw-Hill Book Company, 1959), 236.
[120] V-2 Report # 1 Minutes of the V-2 Upper Atmosphere Panel Meeting, 27 February 1946. Box 34, File Upper Atmosphere Rocket Research Panel, Wexler Papers.
[121] Newell, *Sounding Rockets*, 57 and Rosen and Snodgras, 3.

would be one of the primary Aerobee users), it focused its efforts on producing a much larger launcher, more on scale with the V-2.

On February 18, 1946, NRL's Ernst Krause met with the Navy's Office of Research and Invention (later Office of Naval Research) to discuss procurement of a liquid-fueled very-high-altitude vehicle, the Viking.[122] This launch vehicle would have more thrust than any of the other US rockets, but due to its lighter aluminum skin, would require less thrust than the V-2 to achieve equal heights. Lacking any specialists in liquid-propelled rockets, Krause sent radio engineer Milton Rosen to the Jet Propulsion Lab. There, Rosen recalled, he "found rocket work on a scientific basis." For eight months he studied thermodynamics, aerodynamics, trajectory calculation, and more.[123] NRL would launch twelve Vikings between 1949 and 1955.

This relatively limited production run provided the lab with valuable experience designing and overseeing the construction of reliable rockets and support systems in the years leading up to satellite research. For the Viking, NRL developed a gimbaled motor to steer outside the earth's atmosphere (useful for orbital insertion of satellites or missile guidance). The launch system also featured intermittent gas jets to better stabilize the vehicle after the main power had cut off.[124] After only four trials, Viking had averaged 73

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[122] The Viking was known as the Neptune briefly at first. It is worth note that the Bureau of Aeronautics and Bureau of Ordnance had been the primary sponsors of guided missile research in the Navy.
[123] Rosen, *Viking*, 21. Record Number 002707, Folder "Background Summaries of NASA Top Staff," NHRC.
[124] L. F. Hubert and Otto Berg, "A Rocket Portrait of a Tropical Storm," *Monthly Weather Review* (June 1955), pp 119-124.

miles in altitude and had set a new record of 136 miles' height (outperforming the highest V-2 by 3 miles).[125]

Table 2.1 Viking Launches, Achievements, and Lessons Learned

Viking Number	Launch Date	Peak Altitude (miles)	Notes (Achievements in italics)
1	3 May 1949	50	Premature cutoff due to steam leaks in turbine
2	6 Sept 1949	32	Premature cutoff due to steam leaks in turbine
3	9 Feb 1950	50	Rocket cut off by radio when westward drift was excessive
4	11 May 1950	105	Shipboard firing
5	21 Nov 1950	108	
6	11 Dec 1950	40	Night firing, fins failed, rocket executed violent maneuvers. Temperature day firing.
7	7 Aug 1951	136	*Highest measurement of atmospheric density and atmospheric winds*
8	6 June 1952	4	Rocket broke loose on static firing and destroyed itself
9	15 Dec 1952	135	
10	7 May 1954	136	Motor exploded on first attempt; rocket rebuilt and flown. *First measure of positive ion composition at high alt, highest exposure of cosmic ray emulsions*
11	24 May 1954	158	*Highest alt exposure of cosmic ray emulsion*
12	4 Feb 1955	144	*Highest alt photographs of earth*
13	8 Dec 1956	126	*Vanguard development Test Vehicle 0 (TV-0)*
14	1 May 1957	121	*Vanguard development*

Table derived from "Table 1 Performance Data" and Rosen's *Viking Rocket Story.* [126]

[125] Milton Rosen and Richard B. Snodgrass, "High Altitude Sounding Rocket," (NRL, Washington, D.C., Revised January 1953), 6.
[126] "Table 1 Performance Data" Record Number 006624 NHRC.

The lighter and cheaper Aerobee rocket proved extremely well-suited to the needs, risks, and resources of this incremental science and was used for decades because of this. Explained Herbert Friedman:

> The sealing-wax-and-string approach to instrumenting the Aerobee typified much of our effort in the 1950s. We often went into the field with three rockets to attempt a single experimental objective because the rockets were relatively inexpensive. Mistakes experienced on the first attempt could be adjusted at the launch site by quickly preparing new detectors, for example, on a rudimentary vacuum system-often with liberal use of wax and Glyptal resin paint to cement new windows, seal leaks, and insulate the electronics against corona discharge.[127]

Thus, early sounding rocket research gave engineers experience building durable scientific instruments, maintaining stable and smooth flight, as well as refining skills in tracking bodies and telemetering data—all of which would serve them in satellite and space probe R&D.[128] While many researchers gleaned useful data, others bore in mind the fact that they were biding their time, "going the sounding rocket route" until the resources or mandate presented itself for satellite exploration. Indeed, rocket technology left much to be desired. Between 1946 and 1953, the recovery of data remained a major problem[129] The landings were too rough for even the most rugged instruments. Radio telemetry promised a solution, but itself remained in dependent upon a more refined understanding of the ionospheric disturbances to radio transmission, as well as dozens of engineering woes centered on the "closely packed maze of vacuum tubes, resistors,

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[127] Herbert Friedman, "From the Challenges of WWII to the Frontiers of Space," Cabinet 3, Drawer 2, Bio File, NRL History Office Files, Washington, D.C.

[128] *NASA Sounding Rockets, 1958-1968: A Historical Summary* (Washington D.C.: SP-4401), 14-15. In the foreword, Newell briefly contrasts the "pioneering days" of research with the new broader involvement of university, Government, and other researchers.

[129] Researchers reported that "One of the most important problems connected with the use of sounding rockets for upper-air research is the recovery of data. Some means must be provided for reading the various instruments carried in the rocket and recording the data they yield." Rosen and Snodgrass, 6.

condensers and transformers, every one of which must work perfectly or else the information form the rocket…will be impaired."[130] In this and other ways, rocket engineering itself could jeopardize instruments and data, compromising experiments with vibrations, carrying gases from the ground, and distorting the ambient electrical field.

Even when information was stored on board or telemetered successfully, in many respects it provided too brief a "snapshot" of data or at the wrong time. Liquid-fueled rockets took time to fuel and had to be used within just an hour or two of preparation, making it all but impossible to catch unpredictable solar flares in action. NRL's Heat and Light Division's Ross Gunn, once advised Homer Newell, "It [the rocket] moves too fast. You can't get enough data to get good statistics. So I want you to forget it and do it some other way.'" Newell interpreted his remarks less as a desire to cancel sounding rocket research, but "to find a better way of doing it" in orbital spaceflight.[131]

Regardless of these risks (or perhaps specifically to overcome them one day with satellites), NRL researchers and administrators worked to develop something of a vertical monopoly over rocketry: applying V-2 experience to Viking design, coordinating manufacture with Martin Company, launching the Viking, identifying useful experiments for upper atmospheric research, producing telemetering equipment to send data from rocket to earth, and working up data into scientific papers and reports. Though they had not enjoyed the duration and breadth of resources that the German rocket team had over

[130] Rosen, *Viking,* 164.
[131] Interview of Homer Newell, http://www.aip.org/history/ohilist/4795_1.html. Ross Gunn's career provides another example of the meteorologist as research physicist. http://www.nap.edu/readingroom.php?book=biomems&page=rgunn.html

the years, they were fast catching up to what would become their main competitor for launching the US's first satellite[132]

At the same time, they worked to "market" their capabilities to other scientific communities, sending data and imagery with the US Weather Bureau, circulating it in scientific journals, and at conferences.

Meteorologists' Acceptance of High-Altitude Images

Overall, the Upper Atmospheric Rocket Research Panel was a well-coordinated operation, organizing the human and material resources of roughly two-dozen organizations over more than a decade. Reinforced by the experience of Germany's top rocket engineers, several US defense labs, their university partners, and industrial contractors collaborated in UARRP research, knowingly laying groundwork for US satellite flight. DeVorkin has illustrated how sounding rocketry's early years were colored by an acknowledged reticence among more established scientific communities to accept research results derived from rocketborn instruments. These included the fields of solar physics, ionospheric physics, and atmospheric physics.

Soon after the beginning of V-2 research, UARRP researchers began experimenting with using cameras on rockets to measure the aspect (essentially the tilt) of rockets while in flight. Representatives from at least the APL and NRL offered cloud images to the USWB, and responded positively when the USWB requested duplicate images and negatives of upper air images. USWB Chief, Francis Reichelderfer, quickly grasped the utility of high-altitude images from *rocketsonde* as a potentially useful aid to weather forecasting and even studies of interactions between weather phenomena and

[132] In 1955 the Army Ballistic Missile Agency –more specifically, the von Braun team would submit the Orbiter satellite proposal as an IGY satellite.

land masses. Viewed from above, clouds would provide their own weather map and would aid in identifying weather fronts as well as advancing the study of complicated processes such as tropical cyclones. However, when the primary means of tracking a sounding rocket were optical, research teams rarely fired when cloudiness exceeded 10%. As a result, rockets provided precious few images of large areas of clouds.[133] The few instances in which V-2 Panel and UARRP rockets captured images of cloudcover proved formative experiences to satellite meteorology, noted often in retrospective articles in meteorology journals.

In late 1946, Harry Wexler traveled to Johns Hopkins Applied Physics Lab to have a look at photos taken from a 24 October V-2 launch. A couple months later, USWB Chief Reichelderfer wrote to APL's James van Allen, communicating Wexler's interest in the V-2's cloud photos and communicating his "desire to make an intensive study of these clouds in relation to topography and the prevailing atmospheric currents," certain that when topographical information was paired with imagery of cloud forms, it would help explain "the distribution of vertical currents in the atmosphere."[134] Thus, the WB Chief asked van Allen for a copy of the negative of the photo for a 35 mm microfilm reader, heights and orientation of the rocket on each exposure, along with any other information that may be pertinent. Evidently intrigued by the prospects, he continued, "we hardly need stress the great importance of this high altitude photographic program in

[133] L. F. Hubert and Otto Berg, "A Rocket Portrait of a Tropical Storm," *Monthly Weather Review* (June 1955), p 119.
[134] Reichelderfer to James van Allen, 10 December 1946, Box 3 folder General Correspondence 1947, Wexler Papers. See also Reichelderfer to van Allen 3 January 1947, both in Box 3, Folder General Correspondence 1947, Wexler Papers.

weather forecasting and research." He continued, "since a forecast must use as a point of departure the weather patterns prevailing at the time of the forecast, these cloud photographs would be of definite aid." Reichelderfer communicated that perhaps one day such photos might even be made daily—a significant sentiment given the fact that he did not indicate with *whose* rockets the images might be attained.[135] Likely, he expected the UARRP would do so.

In March of 1947, a V-2 launch vehicle equipped television cameras captured a number of intriguing images for the Panel researchers. That April at a National Advisory Committee on Aeronautics subcommittee meeting on Meteorological Problems, physicist Thor Bergstrahl expressed the concern that rockets were not ideal for regular observations; their expense and complexity made regular, let alone daily, launches impractical.[136] Echoing the sentiment of Ross Gunn to Newell, Bergstrahl observed that sounding rockets "certainly made clear" "that if we had satellites, it would be fantastic."[137] Likewise, Reichelderfer commented that photography from V-2 rockets was "considered to be questionable," likely referring to the expense and complexity of launch, though James van Allen suggested that the cheap Aerobee rockets would at least be viable for at least military weather reconnaissance.

Soon after, the Naval Research Laboratory released report No. R-3083, only two pages of text, but featuring 10 page-size reproductions of the V-2 photography. The following summer, Wexler wrote Newell, requesting eighty additional copies of the

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[135] Reichelderfer to James van Allen, 10 December 1946, Box 3, Folder General Correspondence 1946, Wexler Papers.

[136] Thor Bergstrahl was the physicist in charge of integrating instruments into the V-2 warheads. During the Second World War he had worked on the use of radar for guided missile countermeasures. He also suggested the name for Viking. DeVorkin 144-146.

[137] DeVorkin, 144-146.

"excellent pamphlet" to send to weather stations across the US, "so our forecasters can obtain a glimpse into what may well turn into a potent weather forecast tool in the future."[138] Wexler again communicated his aims for the future, saying, "I hope that sometime soon it will be possible for pictures to be taken from a high altitude rocket showing the entire cloud system associated with a cyclone [hurricane] located in the neighborhood of White Sands."[139] It would be six years before that would occur (covered in Chapter Four).[140]

A few months later, Reichelderfer wrote APL to thank them for sending a duplicate negative of the 24 October 1946 film, saying, "As soon as we receive the auxiliary data [indicating that they were interested in rocket data, not just images] we shall study this film and try to correlate the cloud patterns with upper winds and topography." Additionally, Reichelderfer thanked van Allen for the invitation that the USWB attend an upcoming conference on high altitude photography and that Harry Wexler would be representing the Bureau there.[141]

Thus, the USWB was certainly interested in the use of sounding rockets to support both research and forecasting services and the UARRP certainly interested in sharing their observations with the Bureau. However, sources do not indicate the level of commitment or financing the USWB could attain for such a venture. Nor when. In the

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[138] Wexler to Newell, 28 June 1948, Box 4, Folder General Correspondence 1948, Wexler Papers.
[139] Ibid. Within a couple months, Wexler would receive news that NRL's Krause would transfer to other work and that NRL's Homer Newell would replace him. Wexler wrote the Chairman of NACA "I believe it is important that we maintain direct contact with the V-2 activities and I therefore nominate Dr. Homer Newell" to replace Krause's position on the NACA Tables Committee.
[140] V-2 #40 launched on July 26 1948 also delivered useful images.
[141] Reichelderfer to van Allen 3 January 1947, both in Box 3, Folder General Correspondence 1947, Wexler Papers.

armed services, however, speculation about the utility of satellites became more and more detailed.

Proliferation of Methods & Consensus Building

As the rocket researchers shared images with the USWB to establish scientific credibility (and perhaps out of a desire to expand their base of collaborators), so, too, did they share data derived from *rocketsonde* observations. UARRP coordination fostered a proliferation of methods for making *in situ* measurements of the upper atmosphere. For instance, the Ballistic Research Lab had Warren Berning trained in physics and meteorology and engaged in testing and refining Doppler Velocity and Position (DOVAP) trajectory analysis. While doing so, Berning honed new methods for determining the charge density of the ionosphere.[142] At the Army Signal Corps Lab, William Stroud and Michael Ference used grenade reports (the sound and the flash) to determine the density of the upper atmosphere (at heights as great as these, there is too little air for even a thermometer to be effective and so temperature had to be derived from pressure and/or density of the air.)[143]

Throughout this time, USWB meteorologist Harry Wexler attended V-2 meetings and kept apprised of events, as the Chairman of NACA's Special Subcommittee on the Upper Atmosphere. In 1946, UCLA's Joseph Kaplan wrote Wexler, sharing with him a thesis prospectus for student William Kellogg. Kellogg, who in the next few years would begin working for RAND and turning out reports speculating on the utility of satellites for meteorology, proposed a survey of the "diversity of disciplines which have been brought to bear" on upper atmospheric sounding. "The fact," Kellogg predicted, "that this

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[142] Devorkin, 307.
[143] Rosen, *Viking*, 151-154.

region would be a theater of operations in any future war is partly responsible for this increased interest, and certainly adds a note of urgency to…the course of scientific research."[144] Depending on how one delineates among methods, Kellogg listed at least seven commonly used for direct measurement and indirect measurement of upper atmospheric temperature and composition.[145]

When Kellogg's thesis, "The Atmosphere Above 100 Kilometers" was completed in 1949, he cited references spanning the globe including, the *Proceedings of the Royal Society,* the *Royal Asiatic Society of Bengal Monograph Ser.,* the *Quarterly Journal of the Royal Meteorological Society,* the 1948 Gassiot Committee Report, Oxford University Press, the *Rep. Radio Res of Japan,* the *Proceedings of the National Institute of Science India,* Cambridge Press, the *Indian Journal of Physics,* the *Royal Meteorological Institute of Belgium, Proceedings of the National Academy of Sciences India,* and radio data acquired from Peru, Alaska, and Western Australia.[146] These citations not only indicate the number of places "consuming" atmospheric data and exploring the upper atmosphere (be it through direct means of rockets or indirect such as radio), but they also embody potential collaborators—a gradually accreting global pool of human resources. Within months of Kellogg's completing his doctoral degree, these communities would begin making plans for the International Geophysical Year.

[144] Kaplan to Wexler, 28 October 1947, Box 3, Folder General Correspondence 1947, Wexler Papers.
[145] William Kellogg, Thesis Topic, "Preliminary Proposal for Research on the Structure of the Stratosphere and Ionosphere," Box 3, Folder General Correspondence 1947, Wexler Papers.
[146] William Kellogg, "The Atmosphere Above 100 Kilometers" thesis submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy from University of California, Los Angeles, April, 1949.

Throughout this period, UARRP members struggled to establish accurate and reliable methods of determining atmospheric temperature, pressure, and density. The Army Signal Corps placed instruments in inflatable spheres and dropped them from rockets, telemetering measurements through the course of decent. At the suggestion of Weather Bureau and university researchers, the Army Signal Corps also experimented with grenade "soundings" of the atmosphere, measuring the flash and acoustic signals from the rocket-launched grenades to estimate wind and temperature. Harvard's Fred Whipple opted to photograph meteor tails and used their properties to deduce temperature. The University of Michigan (funded by the Air Force) and NRL (both interested particularly in how ionospheric conditions effected radio propagation) exchanged thoughts at V-2 Panel meetings and during a site visit to NRL.

If collected within the same few hours and cross-referenced, atmospheric snapshots from weather balloons, meteor tails measurements, and sounding rocket experiments could provide some degree of reproducibility in spite of the atmosphere's ever-dynamic conditions. Or so it would seem. Throughout late 1950, UARRP members marshaled resources in preparation for their largest coordinated effort yet, "Temperature-Day." December 11 and 12th of 1950, found the Navy, Air Force, and Army Signal Corps labs setting up for coordinated atmospheric observations alongside Harvard and University of Michigan. Significantly, Sydney Chapman, an internationally renowned geophysicist had attended UARRP's planning meeting that summer.[147] Less than two

[147] At that time, Chapman was on leave from Oxford and working as a research associate at CalTech on an Army Signal Corps Project: nomenclature of the upper atmosphere; points out that the term "upper atmosphere" itself is contextual, depending on the science/researcher. See Wexler papers for 1950 as well as Gregory Good, "Sydney Chapman: Dynamo Behind the IGY," in Roger Launius, James Rodger Fleming, and

months after Temperature-Day had been first proposed, James van Allen and Chapman had discussed for the first time the possibility of what became the International Geophysical Year. David Devorkin points out that throughout these months, Chapman, van Allen, Lloyd Berkner, and other leaders in the field of geophysics had already begun considering a globally-coordinated Geophysical Year, making Temperature-Day an exciting dress-rehearsal for things to come. Anticipating a fruitful "interchange of experiments and techniques" and in particular, long-sought consensus on the NACA Atmospheric tables, the rocket teams transported their equipment and personnel to White Sands, New Mexico (Proving Ground and Army Ordnance Test Station).

Gradually, as data was reduced from observations by sounding rockets, weather balloons, and Whipple's comet observations, the UARRP reached some degree of solidarity in revised temperature-altitude models. With great enthusiasm, James van Allen reflected on the "wealth of experimental information . . . and the impressive degree of concordance of the results from the diverse, independent methods."[148] Van Allen, Ference, Wexler, Newell, and Whipple attended the NACA subcommittee meeting, where NACA encouraged UARRP to publish their results, but "strongly recommended that the paper presenting the summary be so written and titled that it would be obvious that the information is a summary of data and not a proposed new standard for use in rocket work." As an internationally recognized researcher *not* on any of the rocket teams, and whose results were the methodological outlier of Temperature-Day activities, Fred

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David DeVorkin (eds) *Globalizing Polar Science: Reconsidering the International Polar and Geophysical Years* (New York: Palgrave, 2010).
[148] DeVorkin, 290.

Whipple became the man of choice for writing up the final analysis of the UARRP's findings.[149]

The report, without indicating that the UARRP had NACA's authority to set a new standard on atmospheric temperature-altitude tables, did highlight discrepancies between the UARRP and NACA Atmospheric tables and adopted the definitive-sounding title, "Pressures, Densities, and Temperatures in the Upper Atmosphere." Predicting that future tables would be based on *rocketsonde* data, the report stated that continued rocket research was necessary "if we are to master scientifically this domain such a few miles distant."[150] Acceptance was hard-won from the NACA, hesitant to accept the UARRP's data.[151]

Perhaps more important than the slow acceptance of a NACA subcommittee, the emerging research techniques piqued the interest of colleagues abroad, offering hopes of sharing research observations. In April of 1952, the Gassiot Committee invited the UARRP members to attend a joint conference at Oxford University on rocket exploration

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[149] DeVorkin, 292 – 294.
[150] DeVorkin, 294. R. A. Minzner (ed), *The 1976 Standard Atmosphere Above 86-km Altitude: Recommendations of Task Group II to COESA* (Washington, D.C.: NASA SP-398, 1976), 58-59. In 1953, the USWB and Geophysics Research Division of AF Cambridge Research Center cosponsored the formation of a committee on the Extension of the Atmosphere to altitudes above 20 km. Beginning in 1956, Air Research Development Command (Air Force) would publish extended model atmospheres (referred to as an "engineering model atmosphere," reaching above 500 km. Minzner co-edited these. As data began to come in regarding orbital decay of IGY satellites, their inferred atmospheric densities were higher than anticipated and begged a new model. Minzner, *1976 Standard Atmosphere,* 60-61.
[151] DeVorkin, 290-294.

of the upper atmosphere.[152] The Gassiot Committee's mission was described as "to recommend as to the work of the meteorological and magnetic observatories…and to administer…funds applicable to their maintenance."[153] Between the 1952 invitation to the UARRP and their conference in August 1953, the Chairman of the Committee (a physics professor at the University College London) received a phone call from the Ministry of Supply, responsible for military procurement of the British armed forces, asking if the Committee would be interested in performing research using rockets available from the ministry. The UARRP members responded enthusiastically. The Office of Naval Research covered the UARRP's travel and proceedings were published the following year.[154]

RAND Uses UARRP Observations to Speculate on Meteorological Satellites

Whereas the V-2 Upper Atmospheric Rocket Panel images fueled Weather Bureau hopes for more sounding and *more routine* rocket images, in the RAND think tank, they ignited speculation on meteorological satellites for forecasting and research. Shortly after finishing school at UCLA, William Kellogg began work at RAND, Corp. There, the meteorologist made use of UARRP observations to reflect on the utility of meteorological satellites. In 1951 RAND published study R-218 coauthored by Stanley

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[152] The Gassiot Committee dated to approximately 1871, having been set up to supervise the Kew Observatory when it was taken over by the Royal Society from the British Association for the Advancement of Science. This committee soon became the Royal Society Committee dealing with meteorological research. Harrie Massey and M O. Robins, *History of British Space Science* (Cambridge: Cambridge University Press, 1986), see pages 4-7.

[153] Ibid, 5.

[154] *Rocket Exploration of the Upper Atmosphere: Special Supplement (Vol 1) to the Journal of Atmospheric and Terrestrial Physics,* R. Boyd and M. Seaton (eds) (New York: Interscience Publishers, Inc, 1954). Papers in the volume were read at a conference arranged by the UARRP and the Gassiot Committee.

Greenfield and William Kellogg[155] in which they considered the effectiveness of a "satellite missile" or "high-altitude robot" defined as orbiting well above "the uppermost reaches of the known enemy defenses" performing weather reconnaissance."[156] Kellogg and Greenfield correlated photographs taken from UARRP rocket flights with coincident synoptic ground data, speculating on the practicability of weather satellite meteorology.[157] The flights dated between 1947 and 1950 and usable photos ranged from 60-70 miles in altitude. Kellogg recalled how "my favorite professor at UCLA, Joc Bjerknes, had great enthusiasm for the idea of doing a detailed analysis of rocket pictures."[158] In Kellogg's report, classified as Secret when released in 1951, Bjerknes published his own analysis of UARRP images in an appendix.[159]

In their report Kellogg and Greenfield determined that the true value of satellites lay in their routine and broad spatial coverage of land and earth. This would permit meteorologists to identify and track weather systems as they developed over a period of days. The two determined that orbiting between 250 and 500 miles, satellites not only promised a larger field of vision than rockets (which were generally achieving an altitude

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[155] Stanley Greenfield and William Kellogg's 55-page report, "Inquiry into the Feasibility of Weather Reconnaissance from a Satellite Vehicle" RAND Report R-218 (April 1951) was a companion study that grew out of RAND Report R-217 "Utility of a Satellite Vehicle for Reconnaissance." Greenfield and Kellogg based their analysis upon four sounding rocket firings: NRL Viking No. 3, V-2 No. 28 (Air Force Cambridge Research Lab), Aerobee A-7 and V-2 No. 40 (no sponsor/investigator attributed). RAND reports available at www.DTIC.mil.
[156] Stanley Greenfield and William Kellogg, R-218, 2.
[157] *Ibid,* 24-31. Today, this would be referred to as establishing "ground truth," for the remote sensing observation.
[158] Kellogg quoted in, William W. Vaughan and Dale Johnson, "Meteorological Satellites—TheVery Early Years, Prior to Launch of TIROS-1," *Bulletin of the American Meteorological* Society 75 (December 1994), 2297. See also Friedman, *Appropriating the Weather.*
[159] William W. Vaughan and Dale L. Johnson, ibid.

of about 60-70 miles), but that if placed in proper orbit they could remotely sense wind direction and wind shear. In the report, they also analyzed the albedo of a variety of ground surfaces, from those with the lowest reflective properties (cultivated soil and moist earth) to the highest (sea ice, old snow, and fresh snow). The authors noted while an infrared filter would be useful for solving aerial haze between the camera and ground, 500-foot resolutions were generally attainable.

Significantly, Kellogg and Greenfield set their minimum usable resolution at 500 feet—sufficient for studying cloudcover, but not *too* detailed—meaning instruments would be lighter in weight and less expensive. That same year, RAND had published R-217, "Utility of a Satellite Vehicle for Reconnaissance" estimating that:

> For weather observations, resolutions as poor as 500 to 1000 ft can be utilized, although a better minimum resolvable dimension would be 200 ft. This latter resolution is ample to determine a major portion of the characteristics necessary to predict weather. At this resolution, orientation and structure of clouds, direction of winds, and presence of fronts can be seen.[160]

At this time, RAND personnel had begun work on the well-known Project Feedback report, which included the RCA proposal for television cameras operating as an "upper atmosphere station" for observing atmospheric phenomena.[161]

On the Eve of the IGY: "Leadership of a Divided World"

> . . . leadership of a divided world has brought into sharp focus the international aspects of science[162]

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[160] J. E. Lipp, R. M. Salter, Jr, R. S. Wehner, and R. R. Carhart, C. R. Culp, S. L. Gendler, W. J. Howard, J. S. Thompson, "Utility of a Satellite Vehicle for Reconnaissance," RAND Report R-217, 13.
[161] "Project Feed Back Summary Report" R-262 (1 March 1954), 103.
[162] International Science Policy Survey Group, *Science and Foreign Relations International Flow of Scientific and Technological Information* (Washington, D.C.: Department of State Office of Public Affairs, 1950), 5.

It was about this time that the UARRP Panel began to attract interest from communities beyond the United States. In particular, it was at the Panel's 13 June 1950, meeting (the same one that organized the Temperature-day) at which internationally-renowned geophysicist Sydney Chapman visited. Newell attributed great significance to that meeting, noting that from then on the Panel's international contacts broadened as Chapman and other influential figures in international space research visited from Belgium, Australia, Japan, and Canada.[163] This was an opportune time for the US to be hosting international guests. Just one month before, UARRP members who were also in the URSI met informally at China Lake to discuss the possibilities of IGY collaboration.[164]

In May 1950, geophysicist Lloyd Berkner drew attention to US international science policy in two events. First, he made an informal proposal for the International Geophysical Year (at a dinner party celebrating Sydney Chapman's visit.) Also that month, Lloyd Berkner and James Webb submitted their study, "Science and Foreign Relations: International Flow of Scientific and Technological Information" to the US Department of State.[165] Berkner acted as special consultant to Webb, who was the Acting Secretary of the Department of State. Their committee had made a strong case for not only tolerating the status quo of American participation in international scientific

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[163] Newell, *Beyond*, 45.
[164] Marcel Nicolet, "The International Geophysical Year" available at: *www.wmo.int/pages/mediacentre/documents/Int.GeophysicalYear.pdf*
[165] Webb went on to serve as NASA Administrator from 1961 to 1968. "A friend of Lloyd Berkner's and a fellow Naval Reserve officer, Webb was serving as a Director of the bureau of the Budget. There he was one of the Truman Administration's leading advocates of public policy and management reform, and he had taken a special interest, working with Vannevar Bush and the (J)RDB in the problems of enhancing military/science relations and providing for the availability to government of the scientific and technical capabilities of the nation." Needell, 138.

communities, but that Department of State had a responsibility to foster improved relations and increased circulation of scientific knowledge. This could be in the form of visiting researchers, scientific journals, or conferences. Daringly, Webb and Berkner specifically urged the State Department to encourage US scientists to have Soviet contacts.[166]

More than once they quoted Secretary of State Dean Acheson opining that American national and international policy was best as a manifestation of existing practice—it should be a bottom-up reflection of what citizens wanted rather than a top-down relationship of policy dictating practice. Implicitly situating scientific practice among other daily American activities Berkner quoted Acheson at least twice in the report. Acheson invoked classic distinctions between communist and US lifestyles, including churches, businesses and other "natural" manifestations of US life:

> . . . let's dispose of one idea right at the start and not bother with it any more. That is that the policies of the United States are determined out of abstract principles in the Department of State or in the White House or in the Congress. That is not the case. If these policies are going to be good, they must grow out of the fundamental attitudes of our people on both sides. If they are to be effective, they must become articulate through all the institutions of our national life, of which this is one of the greatest—through the press, through the radio, through the churches, and through the labor unions, through the business organizations, through all the groupings of our national life. . . [167]

In their study, Webb and Berkner emphasized the value of collaborating with former and even potential war adversaries, repeatedly using post-WWII policy regarding

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[166] International Science Policy Survey Group, *Science and Foreign Relations International Flow of Scientific and Technological Information* (Washington, D.C.: Department of State Office of Public Affairs, 1950), 78, 91. Regarding the reintegration of Japan and Germany—not only to the world markets, but in the international scientific communities examples on12, 23. Hereafter *Science and Foreign Relations*.
[167] *Science and Foreign Relations*, 86, 5.

Japanese and German scientific researchers as examples of good science policy. Rather than problematize the principle of the US becoming dependent on Nazi science and scientists, they framed the V-2 Project Paperclip and similar postwar programs as successful co-option of formerly enemy resources. By way of being co-opted into the US security establishment, they were necessarily diverted from the new enemy's (read: Soviet) availability. When the US scientific communities were open to collaboration with former—and even potential—adversaries, they stood to gain a better sense of their counterparts' capabilities as well as the promise of their respective fields of study. For instance, in early 1947 the Weather Bureau was hosting a number of Soviet hydrologists, climatologists, geological surveyors, and meteorologists; exchanging thoughts and practical observations as they visited major manufacturing facilities and laboratories in the United States. Yet in September of 1949, Harry Wexler was in communication with the Secretary of the American Meteorological Society concerning the ineligibility of German and Japanese to join.[168] These matters were not to be taken lightly, given the professional risks US researchers took on when maintaining international contacts.[169]

Bureaucratic machinery was still coming into place at this time as, the National Science Foundation was newly established and the federal government was still grasping to reach consensus on a truly comprehensive national science policy. Berkner and Webb opined that old paradigms for state-science relations had allowed a "tacit recognition" and "nominal support" to international science, but that times were changing. The

168 Wexler to Secretary of AMS, 22 September 1949, Folder General Correspondence 1949, Wexler Papers.

169 The Army Signal Corps Research Lab in particular had troubles during the McCarthy Era. See Jessica Wang, *American Science in an Age of Anxiety: Scientists, Anticommunism, and the Cold War* (Chapel Hill: University of North Carolina Press, 1999), 54-55, 264.

international scientific communities were facing mounting problems that demanded the authority and resources of their respective states: international standards, the necessity for international law governing the Antarctic. These questions of practice yielded material problems to be faced and policy to be made.

In reporting on the state of internationalism in the sciences at the time, the two used a recent reorganization in the field of meteorological services to illustrate a rethinking of the state's optimal relationship to science. The committee observed that over the course of more than seventy years, the International Meteorological Organization had "served the cause of international meteorology well." However in recent years, the organization's leadership recognized the necessity to transition from non-governmental status to governmental. The IMO's nongovernmental status functioned as a barrier to meteorologists. As an operating agency, WMO representatives could incur "considerable investments" from nations with an interest in economic development and "rapid technological discoveries and advancements." The IMO re-chartered into the operating agency, the WMO electing USWB Francis Reichelderfer as the first president in 1951. Whether related or not, these events were concurrent with Lloyd Berkner's earliest IGY coalition building.[170]

The WMO differed from the Scientific Unions in that it had a permanent staff and its meetings were regularly attended by civil servants charged with the formulation and execution of state policy. Coordinating, standardizing, routing, and archiving synoptic

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[170] For more on Reichelderfer's perspective on these years, see Box Three, Folders Four and Five of in the Reichelderfer Papers, Library of Congress Manuscripts Division. This was taken from WMO Bulletin, July 1982; Reichelderfer's Corrections to Master Copy pp. 172-183 of the Bulletin.

data from member nations demanded a considerable overhead and a more direct affiliation with the United Nations. Thus the scientific unions operated on much leaner budgets than the WMO, with no permanent staffs and in the words of one member, existed "to promote science, not to utilize it."[171]

Berkner and Webb make clear that the meteorologists reorganized their Organization to better secure and manage state resources. They did this to meet the demands of users of meteorological services—forecasting, climatology, and general research. Berkner and Webb situated the IMO-WMO reorganization in the "context of a vast national economic development and rapid technological discoveries and advancements." "Full exploitation of such advancements through international cooperation—which would involve considerable investments—was not possible without the direct intervention and support of governments.[172] Correspondence within the US Weather Bureau supports this interpretation.

Weather Bureau's Aims at Coordinating Meteorological Research & Services

Meteorologists at the US Weather Bureau wanted to perform their national and international obligations better. By the 1950s, it had become evident that the USWB and WMO faced four inter-related problems. (1) In order to improve standards and services throughout the world, they needed (2) to access to more data from across the Earth. (3) To improve synoptic forecasts in the short term, and the development of numerical weather prediction in the long run, would in turn rely on (4) an improved understanding

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[171] J. Tuzo Wilson, *IGY: Year of the New Moons* (Longmans: Toronto, 1961), 54.
[172] *Science and Foreign Relations.*

of the earth's global dynamic and thermodynamic processes, which also demanded more observations better distributed across the globe.

However in order to do this they had to better coordinate resources on a national level. Months after the formation of the National Science Foundation, USWB Harry Wexler corresponded with USWB Chief Francis Reichelderfer. In a letter titled "New Approach to General Coordination of Meteorological Research Sponsored by the Government," Reichelderfer predicted, on 13 August 13 1951:

> the time may soon be ripe for a new approach to the general planning and programming of meteorological research under the Federal Government. Theoretically, the WB might possibly take a much broader role in planning and coordinating research...[173]

When USWB representatives expressed concerns about coordinating research, it was on a national scale, including both military and civilian resources. In July of 1952, well into the Korean War, Reichelderfer wrote Wexler, then Assistant Chief and the Director of Scientific Services. Therein, Reichelderfer observed that due to a "prolonged period of military expansion and military funds available for all manner of research and development," there was reason for concern regarding a possibly permanent plan by the US military to "invade the civil meteorological field." [174] Reichelderfer allowed that the evolutions in research policy leading to the armed services doing an increasing amount of research and forecasting work—work that normally fell under Weather Bureau—was not deliberately invasive nor treacherous, rather the logical response to perceptions that

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[173] Reichelderfer to Wexler, August 13, 1951, "New Approach to General Coordination of Meteorological Research Sponsored by the Government" Box 5, Folder General Correspondence 1951, Wexler Papers.
[174] July 23 1952 "Plans for New Meteorological Programs" General Correspondence 1952 Wexler Papers.

"progress in meteorology is not as rapid as it should be and that they can do the job" in meteorological research as well as providing meteorological services.

There were a number of scientific fields and meteorological services in question, demanding "Plans for New Meteorological Programs." For one, the Weather Bureau might undertake a survey of all meteorological functions performed by the armed services and USWB, that they might "relieve" the military of otherwise civilian responsibilities. Regarding R&D, Reichelderfer advocated that the USWB "pioneer as much as practicable" the use of electronic computers for numerical weather prediction. So far as meteorological services were concerned, the synoptic network of WBAN stations (Weather Bureau, Army, Navy; later Weather Bureau *Air Force*, Navy) ought to be reorganized, extended, and possibly even elevated within the USWB organizational structure.[175] Since 1947, raw data had been flooding the USWB, leading them to partner with the armed services in plotting and analyzing data to produce as much as 68 weather charts a day.[176] This service demanded 172 persons (98 USWB, 49 Air Force, 25 Navy).

In 1951, the Air Force's Air Weather Service R&D branch contacted the numerical weather prediction unit, the Meteorological Panel, offering to provide funds to Carl-Gustav Rossby and Jules Charney on a five-year renewable contract. While Christine Harper suggests that this specific offer came to naught, the Air Weather Service certainly did enjoy a growing participation in (and influence over) US numerical and hand-prepared weather mapping.[177]

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[175] Reichelderfer to Assistant Chief and Assistant Chief Director of Scientific Services, "Plans for New Meteorological Programs" 23 July 1952, Box 5, Folder General Correspondence 1950, Wexler Papers.
[176] *America's Weather Warriors,* 150-51.
[177] Harper, 156-157.

In practice, meteorologists crossed boundaries among fundamental environmental research, improved forecasting procedures, and ultimately enhancing meteorological services, all necessitating a build up of USWB resources and authority and in the long run and a more explicit coordinating power over US resources. The USWB also sought to make the most of Defense Department resources. At the time of the Korean War build-up (1950-51), Francis Reichelderfer "suggested that if the Weather Bureau would propose one or more projects in research and development in synoptic meteorology pertaining to basic service problems and having general application in military meteorology as well as in the Weather Bureau, the military services would doubtless be willing to finance the Bureau…" The fall of 1952 found Reichelderfer musing over long-term planning for research in synoptic meteorology. The USWB Chief recommended that he and his associate "see what can be done to reshape the pattern of research in meteorology so that the Weather Bureau will eventually be the principal government agency responsible for such research in accordance with the intent of basic statutory authority."[178] In particular, with the formation of the NSF (and word from the NSF Director, Alan Waterman himself), the USWB could anticipate increased funding in fundamental research. Reichelderfer explicitly linked this change to a gradual decrease in military influence over R&D, stating that the USWB would "look toward opening the way for eventual resumption of research responsibilities by the Weather Bureau if and when the military projects in this field taper off…"[179]

[178] Long-Term Planning for Research in Synoptic Meteorology, 12 August 12 1952, Box 5, Folder General Correspondence 1952, Wexler Papers.
[179] Ibid.

In 1954, the US WBAN would expand and move from downtown Washington, D.C. to Suitland, Maryland.[180] In July of that year, the Air Force, USWB, and Navy began collaborating on the Joint Numerical Weather Prediction Unit. Its first director was an officer in the Air Force's Air Weather Service. The USWB was largely reliant on US military for observations, a trend that grew throughout the 1950s. Most USWB observations available were north of the 20 degree north latitude, the least important (and best understood) third of the world atmosphere in terms of thermodynamics and dynamics.[181] Throughout the 1950s, the USWB would remain reliant on the armed services for data from the earth's equatorial region, Arctic, and Antarctic. The Air Force's Air Weather Service stretched operated nine regional centers including Germany, Japan, Guam, Hawaii, and Alaska. Their Global Weather Center was in Offut, Nebraska, Serving Strategic Air Command.

If Reichelderfer was vexed by increasing military influence over research and anticipated a reduction in military support following the end of hostilities in Korea, then expanding his reciprocal alliances (local weather data in exchange for meteorological forecasting services) overseas provided at least a partial solution to the Weather Bureau's want for funds and data. On an international stage, Reichelderfer took the initiative of expressing the notion that it fell to the WMO to aid the developing world. Following a recent Convention, Reichelderfer observed that while many presumed the WMO's objectives were limited to providing "international coordination and meteorological

[180] In one decade, the Suitland facility would serve as the US end of the Soviet-American "Cold Line," sharing first conventional weather observations and later satellite observations. See Chapter Six.
[181] Charles Bates and John F. Fuller, *America's Weather Warriors: 1814-1895* (College Station: Texas A&M University Press, 1986), 148-149.

exchanges," "its Convention shows that it is expected to promote development of meteorology, and we would like to get ahead faster in this aspect as well as in the coordination and exchange features…" The "development of meteorology" demanded a more refined understanding of the upper atmosphere improvement of standards and services of meteorology throughout the world, depended "much upon progress in scientific problems of meteorology…numerical computer techniques…"[182]

[182] WMO Technical Program All Technical Services Divisions Heads and Scientific Services 24 August 1953, General Correspondence 1953 Wexler Papers.

CHAPTER 3
The Promise and the Threats of Satellite Capabilities: UARRP and NAS Coordination for IGY Satellites 1950-1957

> Why are scientists so interested in such a spectacular and expensive undertaking? …During this [IGY] period the scientific efforts of some 40 nations will be co-ordinated to obtain observations on a world-wide scale, observations which will be vital to our scientific progress.
>
> RAND Report, 1956[183]

This chapter addresses the first, but temporary, collaboration between the meteorological community and the sounding rocket-satellite R&D community on meteorological satellites. A total of three meteorological satellite experiments were launched among a host of other proof of concept satellites for the International Geophysical Year (IGY). During this time, Weather Bureau representatives pondered the future of their field, attempting to strike a balance between the needs of forecasters and researchers, but also satellite instruments for forecasting and satellite instruments for fundamental geophysical research.

As an emerging technology, satellites writ large would prove jarringly disruptive to a number of social relationships.

(1) While the UARRP research centers continued to work together on UARRP and eventually IGY planning, interservice competition remained a driving force in the upper echelons of the Army, Navy, and Air Force, all vying to establish capabilities and recognition in the growing fields of missiles and satellites.

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[183] H. K. Kallmann and W. W. Kellogg, "Use of an Artificial Satellite in Upper Air Research," RAND Report P-760 (Feb 1956), 1. Available at www.dtic.mil.

(2) Many, including President Dwight D. Eisenhower, worried that a US satellite program would shift undue resources away from ICBM development, even if the research elements might contribute to missile development in the long run.

(3) Because of the dual-use nature of scientific knowledge, mid-1950s proof of concept satellites breeched barriers between the classified world and declassified.[184] In 1954, planners for the International Geophysical Year (IGY) began openly speculating on the utility of satellites for upper atmospheric observation, geomagnetic studies, solar rays studies, and the like. By inviting the participation of defense labs in the IGY, they temporarily drew a community of satellite thinkers, like William Kellogg, from an R&D world otherwise "muzzled by classification restrictions" into the more public sphere of the International Geophysical Year. In years previous, these same researchers had been engaged in classified studies of strategic and tactical satellite applications: weather reconnaissance, electronic intelligence, image reconnaissance, early warning, and anti-missile studies. When the Eisenhower Administration chose to launch a small scientific satellite in the IGY, they not only funded a stalking horse to establish a peaceful precedent for satellite overflight, they subsidized long-awaited satellite experimentation in the Army Signal Corps Lab, Naval Research Lab, the Army Ballistic Missile Agency, and their research partners.

(4) The commitment to launch scientifically relevant satellites by the end of the IGY would strain already tenuous fiscal relationships among a number of institutions. These included the Congress and the four-year-old National Science Foundation, the NSF

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[184] Whereas the UARRP went out of its way to lay out scientific research as being unclassified, armed service studies for satellite hardware and technique were typically classified. Plans for an IGY satellite were, in fact, classified for several months before Eisenhower's announcement that the US would contribute a satellite to the IGY.

and National Academies of Sciences, and finally the NAS and the armed services' R&D centers (such as the Office of Naval Research, NRL, Army Signal Corps Lab, and Army Ballistic Missile Agency). As representatives of these institutions weighed the pros and cons of pursuing satellite flight, they considered how their accountability could be adversely affected by cost overruns, underestimated lead times, and sundry other shades of failure.

(5) Funded primarily through the Defense Department, but also the National Science Foundation and emergency appropriations from Congress and even the CIA, the UARRP sounding rocket communities recognized the IGY as a once-ever opportunity to prove the performance of their equipment and the validity of their work and (hopefully) secure more sustainable support from military or non-military sponsors. From the very start, this opportunity seemed to be slipping through their fingertips. On a programmatic level, the sounding rocket programs suffered the contracting woes, R&D uncertainties, and mission creep for which defense projects had become notorious. At the national level, between 1953 and 1956, the Eisenhower Administration sought a leveling off of defense spending, first with the New Look reduction in conventional forces and reliance on nuclear (read: Strategic Air Command) superiority and by 1956, transitioning to "sufficiency," presuming superiority of neither the US nor Soviet nuclear arsenals, rather that both were by then adequate for mutual destruction.[185] Military R&D that had risen steadily between 1952 and 1954 began to level and 1955-1957 brought a slight dip in

[185] Iwan Morgan, *Eisenhower Versus 'the Spenders': The Eisenhower Administration, the Democrats and the Budget, 1953-1960,* (London: Printer Publishers, 1990), 75-78.

military R&D as a percentage of GDP.[186] Then, 1957 brought a 10% across the board cut to the armed services, endangering the basic research programs.

(5) And then the unexpected happened. Sputnik brought the perhaps best-known instance of disjuncture caused by these satellites to light: a symbolic shift in geopolitical power resulting in a significant reorganization of defense and nondefense resources (to be addressed more fully in the next chapter). For the IGY researchers, the launch of Sputnik brought chaos before it brought cash. In the months that followed October 4, 1957, a broad range of critics fostered a climate of national emergency. Among these were critics who had accused Eisenhower of permitting a bomber gap (disproven by the first two U-2 flights in 1956) and supporters of the Army's Minimum Orbiter satellite proposal which Wernher von Braun claimed could have been launched at the start of 1957 (before the beginning of the IGY). Citing a desire to catch up in the space race, representatives of the Air Force, Strategic Air Command, Army Ballistic Missile Agency, and Navy Ordnance Test Station all offered "space spectaculars." In varying ways, each of these crash programs would have threatened the carefully-negotiated order agreed upon by international researchers on IGY committees. Using small, quick and dirty satellites with no scientific payload, some advocated top secret launches so that the Soviets would not plan another space spectacular to upstage the US. There was even a proposal to send a Strategic Air Command bomber in nonstop "circumpolar orbit" around the earth to demonstrate the US's strategic reach.

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[186] Alex Roland, *The Military Industrial Complex,* (A Publication of the Society for the History of Technology and the American Historical Association, 2001), 12-13.

The Eisenhower administration maintained the US's policy of scientific-administrative order over empty gestures to raise national prestige. Bringing von Braun's Explorer satellite and the Juno launch vehicle into the IGY launch manifest permitted researchers to launch more instruments on more satellites, but the escalated pace of work would also threaten the existing order of management and operations of highly cantankerous systems.

Jigsaw Sciences and the Earth's 'Heat Engine'

In many regards, satellites were latecomers to a pre-set stage of international scientific activity. The IGY provided a formative experience for thousands of researchers worldwide as representatives of national and private scientific programs pooled data in fields diverse as meteorology, geomagnetism, oceanography, seismology, and the space sciences. Spanning eighteen months from July 1957 through December 1958, the International Geophysical Year necessitated years of planning and coordination. In the United States, funds were secured from Congress via the National Science Foundation, though the National Academies of Sciences consulted directly with the White House and Department of State in defining the scope and objective of scientific activities. Researchers coordinated with their international partners via one of many International Scientific Unions or the operating agency, the World Meteorological Organization (WMO). As of 1955 there were twelve scientific unions including the International Union for Geodesy and Geophysics (IUGG), the International Union of Radio Science (URSI), the International Astronomical Union (IAU), International Astronomical Union (IAU), International Geographical Union (IGU), International Union of Geological Sciences, International Union of Pure and Applied Chemistry, and the International Union of Pure and Applied Physics.

The Scientific Unions and WMO handled organization and funding for the IGY while the Special Committee for the IGY (CSAGI) acted as the governing body. The resulting network of researchers was unprecedented in scope. Forty thousand scientists and technicians represented sixty-seven nations and were distributed at four thousand research stations "blanketing the earth from pole to pole."[187]

Given the fact that the IGY had been born of the International *Polar* Year, the Arctic and Antarctic remained important nodes of activity among a growing network of researchers. Laurence Gould, member of the IGY U.S. National Committee and Chair of the National Academy of Science's Committee on Polar Research reflected on the geographic and epistemic interconnectedness of the sciences, explaining "the jigsaw puzzle of man's physical environment needs pieces which are available only from Antarctica."[188] Making sense of these "jigsaw" sciences demanded a number of geographically distributed stations providing data on variations in geography, glaciology, weather, and climate. Thus, during the IGY twelve nations maintained 48 stations on the continent.[189]

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[187] Arnold W. Frutkin, *International Cooperation in Space,* (Englewood Cliffs, 1965), 16. Frutkin came to NASA after serving the National Academy of Sciences as Director of the Office of Public Affairs. There, he worked on the US committee for the IGY and served as Deputy to the Executive Director of that Committee.
[188]*Ibid.*
[189] Emphasis added. "Statement of Laurence Gould before the Senate Committee on Foreign Relations, June 14, 1960, in support of the Senate's advising and consenting to the ratification of the Treaty on Antarctica signed December 1, 1959." Box 11, Folder 6, Wexler Papers.

A sense of friendly-rivalry laced field activities and lent an air of historic significance to even routine bureaucratic activities. Thus, national defense, nationalism, and the professional drive of research crews proved a boon to a number of scientific disciplines. In July of 1955, Hugh Odishaw wrote weather researcher Harry Wexler, reporting on a trip to London and then Paris while attending an IGY-Antarctic Conference. Having assessed his collaborators, he reported that the British Royal Society had a very strong scientific program, in some regards even stronger than the US. In France he came away strongly impressed by the "increasingly keen competition" by nations trying to outperform one another scientifically and logistically, but also in "mutual aid and in general trying to build up good-will." Regarding the proposed Soviet program, Odishaw noted that it had been "strongly influenced by the US program, even the number and location of their proposed stations."[190] As with sounding rockets and as would be the case with satellites, Soviet scientists were using the high profile of US scientific operations to leverage more resources and intellectual latitude out of their own state. This multifaceted competition in science, mutual aid, and implicitly, national systems of development, made it slightly easier for scientists on both sides to breech barriers and create a productive trading zone for interdisciplinary and international exchange.

In some instances, researchers did quite literally barter. When the USSR voted in favor of assigning the US personnel responsibility for operating the Antarctic Weather Central, it did so with the added provision that representatives from other countries could

[190] Wexler to Odishaw, 11 July 1955 "Some impressions gained during trip to London and Paris in connection with the IGY-Antarctic Conference, July 4-10, 1955" Box 7, Folder General Correspondence 1955, Wexler Papers.

be stationed there. Odishaw observed with evident amusement, "USSR meteorologists in particular could learn much about recent developments in weather forecasting and analysis in the United States; therefore, if the Russians insist on representation, then as a *quid pro quo"* he believed the US should be assigned to the USSR station to learn their geophysical techniques, particularly their coveted capabilities in polar meteorology and glaciology.[191] As for the interest of the French, British, and Norwegians in Weather Central, "if the US is given the responsibility for running the Central, it must organize it the way it sees fit" and they had little interest in unnecessary duplication of resources, sending liaisons to Weather Central to "observe."

At the opposite end of the earth, several nations built new observation posts or expanded existing research facilities, such as the Soviet Arctic Research Institute. Four months before the official start of the IGY, representatives of the Scott Polar Research Institute of Cambridge, England reported "Incidental Intelligence on USSR Meteorology" to their colleagues at the US National Academies' Committee on Meteorology. Therein, they described how their hosts at the Soviet Arctic Research Institute operated. Using data gathered from 600 drifting oceanographic stations, 150 high latitude (not altitude) air expedition stations, air reconnaissance of ice (the forecasting of which remained classified information), and various other ground facilities, the Department of Meteorology and Weather Forecasting's first priority remained the forecasting methods. The department head and most eminent member, G. Ya. Vangengeym, worked using synoptic data spanning 1891 to the present, using no electronic computers but abacuses

[191] *Ibid*.

and "50 to 60 girls…tabulating and working up data."[192] The Leningrad Institute boasted approximately 500 staff members spanning the oft-overlapping scientific disciplines of geography, geophysics, weather forecasting, ice forecasting, and oceanography and was just one example of the hundreds of institutions contributing to the IGY.

Through participation in the IGY, the US and Soviet meteorological communities stood poised to fill their gap in Gould's jigsaw puzzle of the earth environment. For decades, meteorologists across the globe had shared synoptic data through the International Meteorological Organization and later the World Meteorological Organization. Observations of temperature, air pressure, wind speed, precipitation, (and to a limited degree, solar activity) had in turn contributed to other fields of earth science. These were an important raw material to be worked into a refined understanding of global atmospheric processes. Distinguishing "scientific meteorologists" from "the professional" or forecasting "technician,"[193] the NAS Committee on Meteorology laid out its intent to contribute to the research of scientists in other disciplines. These colleagues worried that the field of meteorology suffered from the appearance that forecasting had rendered it too technical and not the rich and diverse field of scientific inquiry as they experienced it. At a meeting to address "manpower in meteorology" attended by the likes of Lloyd Berkner, Hugh Dryden, Francis Reichelderfer, and Harry Wexler, Carl Rosby offered his recent paper on precipitation chemistry as an example of such cross-over interdisciplinary work.

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192 Willard Bascom to NAS Meteorological Committee, Feb 12, 1957, Incidental Intelligence on USSR Meteorology, File AGENCIES & Departments: Interagency Group in International Program in Atmospheric Sc: US Position, 1963. National Academies of Sciences Archives, Washington, D.C. (Hereafter: NAS).

193 NAS Committee on Met Nov. 27, 1956 Meeting at Fermi Institute, University of Chicago with Berkner, Rossby, Byers, Hugh Dryden, Klopsteg, Malone, Reichelderfer, Wexler, and Bascom. File ORGANIZATION NAS: Committee on Meteorology Advisory, 1956. NAS.

Dr. Howard Byers agreed, citing the "university atmosphere" of their field as being just what had attracted the likes of John Simpson and Subrahmanyan Chandrasekhar to study atmospheric physics.

Meteorology: Synoptic Forecasting and Meteorological Science

Lloyd Berkner, Chair of the NAS Committee on Meteorology articulated that the committee's principal occupation ought to be identifying "gaps in the basic meteorological knowledge," dismissing forecasting as a routine "test of knowledge."[194] Fellowships and summer study groups would attract "new men" to meteorology: physical meteorologists, high altitude physicists, and specifically not forecasters. For persons such as these, the work of the IGY would be to establish essential scientific principles governing fluctuations in the earth's atmosphere, not simply gathering data from new remote places.

Foremost among the Committee's objectives was a more sophisticated understanding of the Earth Radiation Budget (ERB), a model for conceiving of the earth's reflection, circulation, and loss of heat from the sun. With great regularity the physicists used the steam engine as an imperfect but vivid model for describing this global transfer of heat energy. The equatorial and mid-latitudes were a firebox; the poles a condenser; the ocean currents and the jet stream were "pipes" transferring energy from the firebox outward to the poles (with occasional "break downs" where hot and cold cells stalled.[195]

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[194] Second Meeting of NAS Committee on Meteorology September 19, 1956 (from Wexler-Cornell notes). File ORGANIZATION NAS: Committee on Meteorology, NAS.
[195] Examples include "IGY 27 January 1959" talk delivered by Berkner to the Industrial College of the Armed Forces. This speech was printed from

Over the course of their planning meetings, the committee laid forth a number of research problems not divorced from weather forecasting, but not identifying weather or climatological forecasting as their sole end. The IGY could be used to establish a reference condition of the chemical composition of the atmosphere to be reanalyzed on a similar scale in the 1980 IGY (carbon dioxide and ozone measurements factored prominently in their interests). Berkner suggested that the community should investigate the causes of long-term climactic instability. They would consider the basic physics of rain and cloud formation and perhaps even the "the rapid retreat of the ice sheets" at the north and south poles. Synoptic radiation surveillance (a study Wexler worked for years to refine) would be "bailed out of abandonment" to improve both research in the circulation of the atmosphere and the prediction of radioactive fallout patterns.

But what of the professional meteorologist or forecasting technician? At this time, computer numerical forecasting was in its earliest stages and the state of the art was regarded as in its nascent form.[196] Forecasters practiced synoptic meteorology, coordinating observations of as many weather systems as possible in as many locations as possible onto a weather map from which experience, college and/or armed services training, would guide them in rendering a prediction. Lloyd Berkner, Chair of the NAS

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http://www.ndu.edu/Library/index.cfm?secID=210&pageID=126&type=section in 2008, but is no longer available. Write LibraryWebmaster@ndu.edu to inquire about access. Speaking to the AMS and American Geophysical Union, "Horizons of Meteorology" to the AMS and the AGU Section of Meteorology 1 May, 1957 Folder AGENCIES & Departments 1963 Interagency Group on International Program in Atmospheric Sci: US Position, NAS.

[196] Christine Harper, *Weather by the Numbers: the Genesis of Modern Meteorology* (Cambridge, Mass: MIT Press, 2008), 151-186; Bates and Fuller *Weather Warriors,* 149-154; Nebeker, *Calculating*, 143-165.

Meteorological Committee, spoke before an audience of the American Meteorological Society and the American Geophysical Union took a far less charitable view of the skill. After gathering the initial data, he described their methods as:

> Then, based on some rather primitive hydrodynamic equations or perhaps just on subjective experience, he is supposed to estimate either in a computer or just in his head, what the circulation and weather pattern will be some hours, days…in the future. At this stage, as a non-meteorologist, I am feeling rather sorry for my meteorological colleagues…at present the uncertainty of hydrodynamic atmospheric flow is such that about three days after determining the circulation patterns, its actual transformation seems to bear statistically no resemblance to any prediction that can be made.[197]

In spite of its limitations, synoptic meteorology was the best practice conceivable with the tools at hand for the US National Weather Service, meteorologists attached to a variety of manufacturing industries, transportation industries, and all branches of the armed services.

Thus even as Berkner, Reichelderfer, Wexler, and other leaders in the field problematized the methods and accuracy of synoptic meteorology, they relied upon these very networks to acquire data for meteorological science. To render the entire field of meteorology—including climatology, aeronomy, aerology, etc.—more rigorous, they had to expand upon pre-existing international synoptic networks to access more data. By the 1960s, Wexler and Reichelderfer would adopt the term of "data sparse regions" to describe large expanses of (relatively) uninhabited land, ocean, much of the poles, and politically inaccessible geographies such as communist China.[198] Francis Reichelderfer,

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[197] Lloyd Berkner, "Horizons of Meteorology" AGENCIES & Departments Interagency Group on Internatl Program in Atmospheric Sc: US Position, NAS.
[198] Memo from Wexler to Reichelderfer, "Contact with Meteorologists of the Chinese Peoples [sic] Republic, IGY Western Pacific Regional Conference, Tokyo, Japan, February 25-March 2, 1957" Folder General Correspondence 1957, Wexler Papers.

for all his desire to distinguish the “scientific meteorologist” from the forecasting “professional,” had been a leader on this front for more than a decade, guiding the IMO through reorganization into the World Meteorological Organization.

To rationalize and enhance the performance of pre-existing synoptic networks, mid-twentieth century atmospheric physicists looked to an arsenal of new and promising instruments for studying the earth’s atmosphere—from a molecular level to the global. Advancements in communication and computation would help manage data on a global scale. Electronic computers would synthesize exponentially more data. Radioactive tracers, radio, and radar all refined conceptions of what constituted a scientific instrument. Members of the UARRP had seen to it that sounding rockets would be recognized as viable platforms for research tools—for both special observations of unique phenomena (such as solar activity and hurricanes) or routine meteorological measurements.[199] For the time being, satellites remained a cost-prohibitive object of speculation.

Satellites Become Feasible

> “Of course we can put a satellite into orbit. All we need is the okay to go ahead, and the money to do the job.”[200]

In the early 1950s the Wernher von Braun vigorously promoted the notion of spaceflight into the public. Between 1952 and 1954, he wrote multiple articles for

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Wexler was surprised at the amount of data coming from China to Japan and was informed that it had been coming in since July 1957 (essentially the start of IGY).

[199] Committee on Meteorology, Sept 19-20, 1956 Second Meeting Notes from Wexler-Bascom, Folder ORGANIZATION 1956 NAS: Committee on Meteorology Advisory, NAS.

[200] Alan Waterman, Director NSF quoted in Martin Caidin, *Vanguard! The Story of the First Man-Made Satellite* (New York: E. P. Dutton & Co., 1957), 250.

Colliers magazine, detailing the ends and means of human spaceflight to the Moon and Mars. Soon after he began work with Disney studios on the movies “Man in Space” and “Man and the Moon,” both of which were aired in 1955. The rocket designer made similar proposals at a variety of scientific and professional societies such as the International Aeronautical Federation and the Hayden Planetarium. In many regards, such postulations were relegated the realm of science fiction by the press and his colleagues. At the same time, colleague Fred Singer, a physics professor at the University of Maryland began making the circuit with proposals for the US launch of “minimum” satellites.[201] While these were far less ambitious than von Braun’s projections, they did draw criticism from engineers and scientists better familiar with more detailed (and classified) studies. In response, the Naval Research Lab’s Milton Rosen and Homer Newell each became vocal proponents of incremental and scientifically relevant space exploration. While the more daring and dramatic proposals of von Braun may have seemed to threaten the credibility of researchers who wished to launch satellites emphasizing scientific utility, they also ignited public awareness and made a field commonly described as “too Buck Rogers” seemingly realistic to a segment of the population.

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[201] George H. Ludwig, *Opening Space Research: Dreams, Technology, and Scientific Discovery* (Washington, D.C.: American Geophysical Union Press, 2011), includes citations for “Minimum Orbiting Unmanned Satellite of the Earth (MOUSE) in the Journal of the British Interplanetary Society, “Astrophysical Measurements from an Artificial Earth Satellite in the published collection of papers from the Gassiot Committee at Oxford England, 24-26 August 1953 to which UARRP members were invited; and “Orbits and Lifetimes of Minimum Satellites” and “Radiation Equilibrium and Temperature” in “Studies of a Minimum Orbital Unmanned Satellite of the Earth” *Acta Astronomica.*

May of 1952 brought the foreshadowings of an important rivalry when von Braun spoke of the promise of a US expedition to the Moon and NRL's Milton Rosen presented a paper criticizing von Braun's plans as "being too far out and being beyond what could be done…using optimistic numbers…there was no margin for error in any of his calculations."[202] Rosen recalled that Willie Ley, German-American science writer and spaceflight enthusiast had wanted to prevent Rosen from presenting his rebuttal, but von Braun insisted that a lack of controversy "wouldn't attract any attention at all."

Later, when Rosen suggested that von Braun himself did not believe his own calculations (though historian Michael Neufeld asserts that he did), von Braun countered less as an engineer and more as a skilled technocrat, "Listen, Milt," he said to the lead designer of the Viking sounding rocket, "you're an American. You should know advertising is everything in America…The way you're talking about space flight, it'll never come. The way I'm talking about it will get people interested, and you'll benefit from it as much as me."[203]

Appealing to engineering rigor, to national security, and at times both, critics like Rosen also had brief forays in the public spotlight. December 1952's *Time* magazine ran a story that included the outlook of "practical missile men" such as Rosen.[204] In it, the article reflected criticisms that von Braun's ostentatious plans overlooked not only critical incremental steps toward the grandeur of human habitation of space, it also threatened to divert resources from guided missile production and sounding rocket R&D, which were already suffering severe reductions in 1952.

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[202] Michael Neufeld, von *Braun: Dreamer of Space | Engineer of War* (Alfred Knopf: New York, 2007), 270.
[203] *Ibid.*
[204] *Ibid.*

In January 1953, Rosen and fellow sounding rocket engineer Richard Snodgrass published a report on sounding rocket performance, special problems, and techniques. The conclusion, undoubtedly written in response to von Braun's recent articles and public talks, reflected on the prospects of space travel. The authors described sounding rockets as the "remote and not the immediate ancestors" to space exploration. Hearkening to the divide between expert knowledge and readers who may not be able to distinguish between fact and fiction, the authors cautioned "reckless predictions of how much time and money will be required to bring [space exploration] about do violence to their scientific integrity."[205] Space travel would come "painstakingly" from the laboratories, industrial plants, and rocket test ranges. But "Any discussion about space travel," they advised, "should start with the bald statement that 'No one can say how long it will take or how much it will cost.'"[206]

It is possible that von Braun's fantastical narratives may have been a method of sidestepping security restrictions covering more immediately viable satellite studies. Unbeknownst to Rosen and likely unbeknownst to von Braun, important discussions of spaceflight *were* taking place at the executive level. At this time, the Eisenhower Administration began retooling policy in a number of ways. Joseph Stalin, leader of the Soviet Union for nearly three decades, died in March of 1953. July 1953 marked the end of the Korean War and soon after, the US and Soviet Union were on speaking terms regarding nuclear disarmament. Eisenhower announced his carefully calculated proposal

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205 Milton Rosen and Richard B. Snodgrass, "High Altitude Sounding Rocket," (NRL, Washington, D.C., Revised January 1953), 7.
206 Rosen and Snodgrass, 7.

for an Atoms for Peace initiative in the UN, December of 1953.[207] Similarly, significant changes were taking place in the Eisenhower White House favoring the establishment of satellite overflight for reconnaissance purposes. The Technological Capabilities Panel chaired by James Killian recommended that the US launch a small scientific satellite to establish freedom of space (the final report was presented February 1955).

In June of 1954, the President submitted a supplemental IGY budget for FY 1955, including a small, instrumented satellite to be used for geophysical measurements.[208] Funding for the satellite program would be independent of the entire IGY line, the money would be appropriated by Congressional action and not at any point be allocated to the DOD: "In noway [sic] is this to be a part of existing IGY activity."[209]

The Meteorological Community Considers Satellites

By 1954, USWB's Harry Wexler was widely recognized as a proponent of the use of satellites in meteorology, fueled in part by achievements in UARRP *rocketsonde* technique, ongoing correspondence with physicist and satellite enthusiast Fred Singer, as well as RAND meteorologist William Kellogg. Due to the fact that sounding rockets were rarely launched in more than 10% cloud cover, there were few cloud images that meteorologists could study. In the days of V-2 rocketsondes, the Weather Bureau expressed interest in photos retrieved from two launches, one in late 1946 and the other March of 1947 (detailed in the last chapter). October 5 of 1954 brought new excitement to the Weather Bureau—an NRL Aerobee rocket fired during a large opening of cloud

[207] See Krige, "Atoms for Peace, Scientific Internationalism, and Scientific Intelligence," pp. 161-181. *Osiris* 21
[208] Needell, 319.
[209] Newell handwritten notes 9 March, 1955 Technical Panel on Earth Satellite Program. File USNC Member Files: Newell H. E.: Technical Panel on Earth Satellite Program Meetings: Notes 1955-1956, NAS.

cover over White Sands Proving Ground had unexpectedly captured the picture of a tropical storm "and one associated vortex."[210] This "atmospheric monster," reported an ONR research review, "with its spiral tentacles, embraced an area of more than 1000 miles in diameter."[211] Of greater significance, the storm was as-yet unpredicted by forecasters—the sounding rocket images had been the first indication of the hurricane. Later named Hazel, this hurricane had been identified while it was near Grenada and moving west-northwest. Making landfall in North Carolina Hazel proceeded to plow its way north. The storm retained hurricane force winds moving rapidly through Virginia, western Washington, DC, and into Ontario.

The soon famous October 5 sounding rocket image had been derived from a 16-millimeter motion picture camera mounted in the Aerobee nosecone. After shooting (in both senses of the word) it was separated from the last stage of the rocket and parachuted back to earth. Researchers reported that the camera had been equipped with a semi-telephoto lens and was capable of taking six pictures a second. At approximately 100 miles altitude, the rocket rolling on its axis and gradually tipping downward allowed enough time for several overlapping swaths of the earth to be imaged. Back on earth, researchers reproduced and enlarged 90 prints of the color film and assembled them into a mosaic. The mosaic was analyzed in an issue of the *ONR Review* and the American Meteorological Society's *Monthly Weather Review* where it was printed in black and white. The authors of the AMS article directed their readers to the September 5 issue of *Life* magazine where they could find the mosaic in full natural color.

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210 L. F. Hubert and Otto Berg, "A Rocket Portrait of a Tropical Storm," *Monthly Weather Review* (June 1955), 119.
211 OttoBerg, "High-Altitude Portrait of a Storm," *ONR Research Reviews* (Sept. 1955) pp. 12-18.

When USWB and NRL researchers shared their analysis of the Aerobee mosaic in the AMS article submitted July 8, 1955, they predicted that the Kodachrome images "may well launch the era of rocket photo-reconnaissance for meteorology" but signaled a reticence in the scientific community regarding satellites.

> Techniques that will be developed by rocket reconnaissance of hurricanes may find wider application in an expanded program of ultra-high altitude meteorological reconnaissance. Dr. Harry Wexler of the U.S. Weather Bureau has discussed the utility of such ultra-high photography in connection with hypothetical synoptic situations.[212]

Making no reference to satellites by name, they opted to endnote Harry Wexler's September 1954 article "Observing Weather from a Satellite Vehicle" published by the *Journal of the British Interplanetary Society*. Nevertheless they communicated the clear message that sounding rocket technique could facilitate the transition to the use of satellites.

Later that fall, RAND Electronics Division's William Kellogg wrote to his friend, Harry Wexler thanking him for copies of Wexler's British Interplanetary Society article. Looking forward to the AMS symposium that January, Kellogg hoped that Wexler would "bring along your famous colored slide," noting that his satellite talk would provide useful background for Stan Greenfield's analysis of specific synoptic situations.[213] Kellogg, who would soon serve on the Working Group for Internal IGY satellite Instrumentation, remained extremely supportive of his colleagues at the USWB with whom he collaborated with on a number of synoptic studies pertaining to atomic fallout.

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[212] Hubert and Berg, pp. 119-124.
[213] William Kellogg to Harry Wexler, November 29, 1955. Box 7, Folder General Correspondance 1955. See also James Fleming, "A 1954 Color Painting of Weather Systems as Viewed from a Future Satellite," *Bulletin of the American Meteorological Society* 88 (Oct. 2007), pp. 1525-1527.

Meantime, Kellogg and Greenfield published a number of studies and presented at a number of conferences predicting the form and function meteorological satellites must take to reach their full potential.[214] In June the coming year, Kellogg would publish another co-authored report with Kallman, Research Memo 1500, "Scientific Uses of an Artificial Satellite."

The Sounding Rocket Community Before Satellites

As IGY planning commenced, developers of sounding rocket systems had only recently proven the efficacy of their systems for observing upper atmospheric temperature, pressure, wind speed and direction. On 7 October 1953, the Panel reviewed results from the Gassiott Committee symposium and discussed their upcoming participation in the IGY. In February of 1954, they selected members for the Special Committee for the IGY (SCIGY) to work on Arctic firings. In IGY preparation, the Weather Bureau had sought unsuccessfully to secure federal support for a geographically diverse synoptic IGY rocket network (on behalf of the DOD, meaning that they likely did so anticipating the armed services would be able to fund it). By Reichelderfer's observation, the only times sufficient sums of sounding rocket money had been when they were "squeezed out of military appropriations 'for national defense purposes.'"[215] UARRP members would have readily agreed with that assessment, particularly the

[214] Examples include: Kallmann, H. K., Kellogg, W. W.; Rapp, R. R.; Greenfield, S. M., *Scientific Uses of an Artificial Satellite* (RAND Corporation: Santa Monica, CA, 06 September, 1955); Kallmann, H. K.; Kellogg, W. W.; *Use of an Artificial Satellite in Upper Air Research* (RAND Corporation: Santa Monica, 15 February, 1956); Greenfield, S. M.; Kellogg, W. W., *Satellite Weather Reconnaissance* (RAND Corp: Santa Monica, 12 June, 1958).
[215] Francis Reichelderfer to Dr. J. G. Morse, Martin Marietta Corp., 31 August, 1967. Box 4, Folder 7 of Reichelderfer papers, LOC Manuscripts Division (hereafter, Reichelderfer Papers).

semantics of "squeezing out" funds from military appropriations. In the end, members of the IGY Executive Committee would fret about the concentration of funds at one location (Ft. Churchill, Canada) with "Too little geographic spread!!"[216]

In the fall of 1954, Joseph Kaplan, Chair of the US National Committee of the IGY wrote Allan Waterman, Director of the National Science Foundation. Perhaps unnecessarily he reminded Waterman that the Defense Department represented the US's primary source of scientific and engineering knowledge of *rocketsonde*. In his letter, he alluded to the last nine years of UARRP collaboration over which the institutions had developed extensive networks among commercial suppliers and contractors that could now be put to use "most economically" by the US IGY program.[217] Having observed these formalities, Kaplan explained that he was requesting a two-year advance on funds for the procurement of sounding rockets—already notorious for their long lead time.

The state of *rocketsonde* funding sets the tone of fiscal risks and uncertainties in upper atmospheric research and also helps put the magnitude of the Vanguard satellite investment and risk in perspective. Already, as opposed to the synoptic *rocketsonde* network requested by Reichelderfer, UARRP members made due with firings at White Sands Proving Ground; Holloman AFB (near White Sands); Fort Churchill, Canada; San Diego High, California; the Antarctic; and from ships at sea. As of September 1955, the NSF covered the cost of sounding rockets, facilities, support contracts, and travel for select individuals, amounting to $1.7M. The US armed services and one university, the

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[216] US National Committee IGY Executive Committee Eight Meeting 22 June 1955, Box 7, Folder General Correspondence 1955, Wexler Papers.

[217] Letter and memo to Allan Waterman from Joseph Kaplan and Homer Newell, September 25, 1954 (memo undated) File Rocketry Naval Research Lab, 1954-1960, NAS.

State University of Iowa, covered the cost of research programs and logistics with money supplied through ONR, other DOD organizations, and for a couple experiments, the Atomic Energy Commission. The participants were all UARRP members: the NRL ($2M), Navy logistical support ($2.4M), Iowa State University ($0.2M), GRD/AFCRL ($1.7M), ASRL ($1M), Army Ordnance ($0.5M), total Army logistics and support ($3M).[218]

Homer Newell, UARRP representative to the Special Committee for the IGY (CSAGI) and chair of the CSAGI Rocket Working Group directed the expenditure of all US DOD rocket funds.[219] The sum total, $14.8M, was substantial, but a decade of R&D had demonstrated that investment in a rocket was far more expensive than vehicles on sea, land, or the lower atmosphere. Speaking of the upper air program at the NRL, Newell explained:

> The cost of the program, however, is about twice that of a normal laboratory research program, because of the need for rockets, launchers, telemetering ground stations, special airborne equipment, and expeditions to remote locations such as the Artic, Antarctic, and the mid-Pacific. The cost is about $45,000 per man per year as opposed to about $25,000 per man per year for normal research…The program would have gone under…had not the International Geophysical Year [funding] rescued it.[220]

In addition, there might be delays do to repairs that would incur "standing army" costs for the launch crew. Contractors might for any number of reasons experience

[218] "Summary: Cost Break Down by Agency IGY Rocket Program," 26 September, 1955, file Rocketry Naval Research Lab, 1954-1960, NAS. Overarching financial information was included in the NRL file because the expenditure of all sounding rocket funds were "under the direction, and shall be the responsibility, of Dr. Homer E. Newell, Jr. by and with the advice and consent of the U.S.R.R.P. [sic, this is without a doubt a reference to the UARRP] Special Committee for the IGY."
[219] This is as of September 25, 1954. A.H. Shapely directed funds related to ionospheric and auroral rocket programs for the National Bureau of Standards.
[220] Satellite and Missile Programs Hearings Part I, 370.

overruns—modification orders, extension of completion dates, and the like. A rocket may (go off course) and have to be destroyed without ever gathering or telemetering data. Cloud cover might scrub the launch of a rocket intended to observe a time-sensitive event, such as the observation of an eclipse. An instrumented rocket alone was uncertain enough without adding a second and third stage and attempting orbital insertion at an altitude never before analyzed by a sounding rocket. Since 1946, these communities had speculated and calculated. Better than any other community, they fathomed the technical complexities, risk to professional prestige, and sheer investment of time and energies in launching a *scientific* satellite.

IGY Administrators Consider Satellites

In the summer of 1953, at the International Astronomics Federation and again at the Hayden Planetarium's 1954 symposium on space travel, Fred Singer made proposals for a Minimal Orbital Unmanned Satellite, Earth (MOUSE). Singer, a professor at University of Maryland and friend of both Lloyd Berkner and Wernher von Braun, kept in contact, too, with USWB's Harry Wexler. The same handful of individuals crossed paths many times for their professional duties and IGY preparations. Wexler, despite his many obligations at the USWB and for the IGY found time to present at the Hayden 1954 symposium as well, speaking on the promise of "Observing the Weather from a Satellite Vehicle."

As the International Scientific Unions were preparing plans for the IGY, in August 1954, Singer spoke before the International Radio Science Union (URSI) on earth satellites and soon after, Berkner endorsed URSI's recommendation for an earth satellite to be flown in the IGY. After URSI and the IUGG had passed resolutions favoring the principal of inviting satellites as contributions to the IGY (in August and September of 1954), CSAGI still had not yet approved.

Such machinations aligned national and transnational interests. The US did indeed require a certain scientific authenticity for the stalking horse satellite. At the same time US satellite enthusiasts such as Fred Singer viewed this as an opportunity to influence international science policymaking. His and Berkner's proposals to the URSI, the IUGG, and ultimately CSAGI functioned to build an (albeit temporary) community of researchers vested in the success of a scientific satellite launched by the US and perhaps the Soviet Union.[221]

With the funds soon to be appropriated and a clear presidential mandate, several influential IGY representatives still voiced reservations about pursuing a satellite program. Newell, who had invested his last decade in building the scientific sounding rocket program and was at the time director of all DOD funds for sounding rockets spent months cautioning colleagues against the high risk and technical uncertainties of placing a working satellite in usable orbit and getting viable data back from it.

Years later, Singer would suggest that Newell had been opposed to satellites altogether. Newell maintained that his opposition was not to satellites *per se,* rather to the means by which Singer proposed one be brought into being. Singer's confident approach to the minimal satellite proposals was overplayed in the interest of making it sound inexpensive and easy, if not flippantly so. Newell and the sounding rocket community he represented were also deeply concerned about the hard-won legitimacy of the sounding

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[221] Bulkeley and Needell have parsed out the documents and logics by which Berkner may or may not have been privy to the TCP or FEEDBACK reports and thus, the degree to which their satellite proposals to URSI, IUGG, and CSAGI had been directly influenced by policy geared explicitly for clearing the way for reconnaissance satellites.

rocket program. Recognizing the tenuous nature of IGY financing, he feared that satellites would somehow come at the expense of the more reliable and newly-accepted *rocketsonde*. The preparation for and execution of the IGY posed a one-time opportunity to the sounding rocket community to underscore its international scientific relevance, to gain access to unprecedented geographic locations, and secure much-needed funding for upper atmospheric research. The satellite project was just shy of an existential gamble: losing dwindling sounding rocket (read: UARRP) resources to a satellite of negligible scientific credibility would only add insult to injury.

The opening of Chapter Four details the financial straights of the sounding rocket community and the perception that IGY R&D funds kept many research centers from running out of sounding rocket research funds altogether. The UARRP community's reservations about satellites were justifiable. Many within the DOD were aware of a classified Air Force Study estimating the cost of launching a satellite at $100M.[222] Other figures considered were $150M or as low as $82M.[223] Years later, James Killian reflected, "was the Vanguard ever a good bet?" Wanting to get as much "ball for a buck," Killian, too, realized that initial estimates of cost "were so low that the project suffered

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[222] Newell handwritten notes 9 March, 1955 Technical Panel on Earth Satellite Program. File USNC Member Files: Newell H. E.: Technical Panel on Earth Satellite Program Meetings: Notes 1955-1956, NAS. At least one AF Brig. General used this figure to dissuade the US from pursuing a satellite program in 1949 on the logic that the US economy could not withstand the burden. Christopher Gainor, "The Atlas and the Air Force: Reassessing the Beginnings of America's First Intercontinental Missile," *Technology and Culture* April 2013, 355.
[223] Ludwig, 72.

from inadequate financing throughout its history."[224] Thus, when preliminary (and low-balled) estimates of an earth satellite ranged from $15M to $20M between 1954 and 1955, they not only surpassed the $14.8M allocated for sounding rockets, they also promised astounding cost overruns, the risk of funds being pulled from other programs, and the severe re-scoping of related projects (i.e. sounding rockets).

Perhaps one of the most critical moments leading to the inclusion of a satellite in the IGY took place at the informal gathering of CSAGI members in Rome. Lloyd Berkner, the powerhouse behind the IGY invited ten colleagues to his hotel room. These included Joseph Kaplan, US National Committee chair, Hugh Odishaw, committee secretary, Athelstan Spilhaus, Dean of the University of Minnesota's Institute of Technology, Harry Wexler of the USWB, Alan Shapely of the National Bureau of Standards, Homer Newell of the NRL, and Fred Singer of the University of Maryland. The meeting took a more urgent air when attendees discussed the November 1953 announcement of Soviet Academy of Sciences' A. N. Nesmeyanov, stating that satellite launchings and even moon probes were within Russian capabilities. Very recently, the USSR had committed to participate in the IGY (though they would not announce their intent to launch a satellite for the IGY until August 2, 1955—hours after the US had made it's own announcement).

At the meeting, Singer dominated discussions of the technical challenges and capacities of an earth satellite, with Newell interjecting to point out technical challenges

[224] James Killian, *Sputnik, Scientists, and Eisenhower: A Memoir of the First Special Assistant to the President for Science and Technology* (Cambridge, Mass: MIT Press, 1977,) 119.

such as the likelihood that batteries would bubble in zero gravity.[225] Years later Newell would assert that he and other colleagues in the DOD had in most settings been "muzzled by classification restrictions" and therefore "could not engage Singer in debate…could not point out that Singer's estimates overshot the mark somewhat, and that his suggested approach was not as workable as others that couldn't be mentioned."[226] Perhaps because formal proposals were already circulating, at the informal gathering Newell spoke up more than usual and gained a reputation as a naysayer. He first pointed out detailed technical shortcomings in Singer's satellite plans and later, returned to his apprehensions about sounding rocket funding. Whatever the details of the meeting, reassurances must have been made to put Newell's mind at ease, for the men voted unanimously for CSAGI to endorse the use of satellite instruments in the IGY.

By November 1954, Newell was in full support of an IGY earth satellite. That month he contributed to an influential American Rocket Society report on which Milton Rosen was the chair. The report was careful to not designate what sort of launch vehicle ought to be used for such a satellite. It featured six appendices from researchers at a variety of institutions explaining the utility of satellites for astronomy, biomedicine, communications, geodesy, meteorology, and observation of the ionosphere. In keeping with the stance of the Navy researchers, the report explained that "to create a satellite merely for the purpose of saying it has been done would not justify the cost…the satellite

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[225] Singer would later recall: "it's quite interesting that the opposition to this came primarily from Homer Newell who was in charge of the rocket program at NRL and who was concerned that an emphasis on satellites could jeopardize the funding for the rocket program." Fred Singer in interview of Dr. Fred Singer by Allan Needell and David DeVorkin, 23 April 1991, AIP Collection, http://www.aip.org/history/ohilist/28613.html; Needell *Science, Cold War*; and Green and Lomask. *Vanguard.*

[226] Newell *Beyond,* 52.

should serve useful purposes…which can command the respect of the officials who sponsor it, the scientists and engineers who produce it, and the community who pays for it."[227]

This recurring principle of accountability to the state and citizens coupled with the moral ramifications of *International* Geophysical Year participation offered in the eyes of some, a culturally and diplomatically superior case for spaceflight. In time, this "higher ground" would help justify scientific payloads and extensive ground support systems impossible to attain with a "minimal" one- or two-shot launch plan.

In spite of guaranteed executive level support and CSAGI's official indication of interest, many members of the scientific community maintained a critical bent. In January 1955, the IGY Executive Committee set up a special study group to investigate the feasibility of satellites. This panel was originally known by the ambiguous name, the Technical Panel on Rocketry, but adopted the even more evasive "LPR" committee (for Long Play Rocket) in both formal and informal circumstances. NASA's official Vanguard history indicates that part of this "LPR" obfuscation was due to the fact that the NAS had not yet committed to participating in the program and wanted to avoid premature publicity under "protective coloration."[228] All the scientists on the panel would have remembered the public response to the first atomic bomb blasts.[229] Years later in an oral history, Homer Newell would suggest that this was also due to concerns over of a

[227] Green and Lomask, 16.
[228] Green and Lomask, 25. Interview of Homer Newell, http://www.aip.org/history/ohilist/4795_1.html.
[229] Paul Boyer, *By the Bomb's Early Light: American Thought and Culture at the Dawn of the Atomic Age* (Chapel Hill: University of North Carolina Press, 1994).

public uprising against scientists. “The idea was that the long playing rocket wouldn’t be scary. People would just relate it to what’s been happening for the past ten years.”[230]

In the March 1955 meeting of the LPR committee, there was much productive discussion of satellite instrumentation, support networks, and cautious estimates of cost.[231] Merle Tuve, whose deep concerns over the preservation of pure science—pure in the sense that it was unadulterated by national defense demands—voiced his reservations over the budding satellite program.[232] Given its undeniable origins in armed services studies and labs, he believed that it ought to be funded and executed openly by the military. Fred Whipple and Athelstan Spilhaus clarified the NAS’s interest in the program, alluding to the necessity of easing “permission to go over other countries” and also to the probability that Defense Department would one way or another see to it that satellites were launched in the near future. Additionally, by demonstrating to their Soviet peers that the US IGY program was not actively controlled by the military, they would facilitate the work of their international colleagues, clearing papers for publication and gaining permission to attend conferences, workshops, and the like.[233] Tuve adamantly opposed while other members remained wary of dealing with an as-yet classified satellite program and the international controversy it might bring.

[230] Interview of Homer Newell, AIP Collection, http://www.aip.org/history/ohilist/4795_1.html.
[231] Newell handwritten notes, USNC-TPR-LPR Meeting 9 March, 1955. File USNC Member Files: Newell H. E.: Technical Panel on Earth Satellite Program Meetings: Notes 1955-1956.
[232] This is not surprising given the fact that Tuve functions as a foil to Lloyd Berkner throughout Needell’s *Science, Cold War,* resistant to the notion of compromising “pure” science to military sponsorship or demands.
[233] Needell, 336-338.

On 26 May 1955, the National Security Council approved plans to orbit an IGY satellite, providing it did not interfere with ICBM development, but that by no means guaranteed that the IGY Executive Committee would welcome the instrument. On 2 June Dr. Wallace Joyce, a geophysicist with the Navy Bureau of Aeronautics, articulated a common concern regarding cooperation with the Defense Department. Members of the LPR committee had anticipated that the satellite budget would be part of a supplemental budget going before Congress. However, Joyce explained that his extensive experience with guided missile work had convinced him that "and the amount of effort in such programs was always underestimated." Thus, he advised that considerable development work was necessary by the DOD before the satellite could be integrated to IGY budgeting.[234] (This reputation of defense, and particularly rocket and missile, developers underestimating the cost of work will be addressed more in the chapter conclusion.)

Nevertheless, in early July 1955, the NRL Rocket Development Branch, Rocket Sonde Branch, Atmosphere and Astrophysics Division, Electron Optics Branch, and Optics Division published Memorandum Report 487, "Scientific Satellite Program."[235] Emphasizing the necessity of contributions from a wide range of scientific experts, the report recommended that the NRL function as primary scientific responsibility for the satellite program.[236]

On August 2, 1955, President Eisenhower formally announced selection of the Vanguard satellite system. IGY critics rightly predicted that early proponents of an IGY

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[234] Suggested Procedure for Activities of Program and Projects, 21 June 1955, Box 7, Folder General Correspondence 1955, Wexler Papers.
[235] Scientific Satellite Program, declassified (formerly secret) NRL Memo Report #487 July 5, 1955. RN 006624 Stewart Committee Vanguard, NHRC.
[236] Ibid.

satellite had underestimated the cost. On 8 September 1955, the budget estimate was doubled to $28.8 million. Historians have suggested that Vanguard was selected because the Navy was the only service that would not have to divert resources from ICBMs to launch a satellite. Historians have suggested that the Army Orbiter proposal was not selected due to racism and nationalism. They have also suggested that the decision was made by Stewart Committee members voting along lines of long-standing service rivalries, rather than the proposal's actual merit. Historians have even, in an obtuse fashion, suggested that Vanguard was selected because it's long development time would guarantee a Soviet lead into space.[237] Vanguard satellite system was at its core, a more capable scientific instrument than its counterparts and was put forth by a research lab with more than a three-decade long record of upper atmospheric research.[238]

Though all three services submitted proposals when requested, it is widely accepted that the Air Force proposal was soon dismissed, leaving the competition to the joint Army-Navy Orbiter proposal (offered by the Army Ballistic Missile Agency) and the Vanguard. Neither the Air Force nor Orbiter proposal included specific details of how satellite tracking would be carried out. The Orbiter was projected to weigh a mere five pounds, placing harsh limitations on scientific payloads. The Vanguard proposal allowed for 10 pounds for the scientific instruments, 2 pounds for Minitrack instrumentation, 2 pounds for telemetering equipment, 12 pounds for batteries, and 8 pounds for the spun aluminum sphere structure.[239]

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[237] See McDougall, Neufeld in *Reconsidering Sputnik,* and Stares, *The Militarization of Space.*
[238] Launius, 22 also addresses scientific pedigree.
[239] NRL Memo Report 487, 20.

On 27 October 1955, the UARRP held a symposium to select instruments for the IGY satellites. Proposals were only accepted from UARRP member institutions and only unclassified experiments were allowed.[240] The following January, in celebration of the Upper Atmospheric Rocket Research Panel's ten-year anniversary, UARRP members presented thirty-eight talks summarizing a variety of earth satellite experiment proposals and research studies. Experiments included studies of the satellite system itself (such as methods of tracking, measuring the influence of atmospheric drag on the satellite, and influence of micrometeorites, in addition to the use of satellites for remote sensing: meteorology, observation of ionospheric activity, and use of orbital computations to calculate the earth's geomagnetic properties.[241]

The Symposium featured several papers contributing to meteorology, with strong representation of Air Force interests. One researcher from Princeton University Observatory spoke on determining air density with a satellite; one from the University of Michigan addressed pressure and density measurements; William Stroud and his partner William Nordberg, of the Signal Corps, presented on their meteorological instruments; an Air Force Cambridge Research Center researcher spoke on heat transfer; Fred Singer of the University of Maryland presented a paper on meteorological measurements; Air Force Cambridge Research Center researchers also speculated on visibility from a high altitude satellite; and the third paper offered by AFCRC. University of Michigan, the

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[240] Ludwig, 80-81.
[241] Tenth Anniversary Meeting of the UARRP "Symposium on Scientific Uses of Earth Satellites" p 25 v-2 panel stewart com, van xfer

fourth institution likely funded by the Air Force, addressed the upper atmosphere and insulation of a satellite.[242]

The Vanguard System: Prelude to TIROS

Project Vanguard
1. Launch Sat.
2. See it.
3. Use it.[243]

Because the Eisenhower Administration and NAS insisted that satellites be credible scientific instruments (and not one-off stunts) they wittingly and unwittingly laid infrastructure for what would become the NASA-TIROS satellite system. The quote above indicates that it was not enough to simply launch a satellite into orbit. The three steps were in many regards interdependent: improper orbital insertion would jeopardize the payload's efficacy; tracking was necessary for assuring proper orbit and for operations of satellite (in particular being able to perform command and data acquisition when the satellite passed over a station's radio horizon.) While the Vanguard system's scientific credibility (as a US contribution to the IGY and stalking horse assuring the world of the US's peaceful intentions in spaceflight) was important to the Eisenhower administration, as schedules slipped, experiments were added, and support systems refined, Eisenhower did at last complain that the Project was getting "bogged down" and in particular, that it was due to the extra scientific instruments. The President reminded his scientific advisors in frustration "Such costly instrumentation had not been

[242] Tenth Anniversary Meeting of the Upper Atmosphere Rocket Research Panel, 10 January 1956. Record Number 000884 NHRC.
[243] Newell handwritten notes 9 March, 1955 Technical Panel on Earth Satellite Program. File USNC Member Files: Newell H. E.: Technical Panel on Earth Satellite Program Meetings: Notes 1955-1956, NAS.

envisaged" and "stressed that the element of national prestige…depended on getting a satellite into its orbit, and not on the instrumentation of the satellite."[244]

"Launch Sat:" From Viking to Vanguard

The Viking sounding rocket program proved an important R&D experience. In 1955, the Viking, Aerobee-Hi, and Sergeant rocket motors re-emerged in a three-stage test vehicle, intended to carry Vanguard satellites into orbit. Thus, the last two Vikings were removed from their research manifest and used as engineering prototypes in static tests for the Vanguard launch vehicle.[245] Diverting the last two Vikings (one sixth of the run) to the Vanguard project likely reduced procurement costs for Vanguard and/or transferred the expense of those last two launches from one project line to another (Viking to Vanguard). Having reached the end of their 1940s "surpluses" and fighting tightening DOD budgets, Viking fast became too expensive for her users. Homer Newell explained, "The groups engaged in rocket sounding each had perhaps a few hundred thousand dollars a year to expend on the research, and a single Viking would have eaten up the whole budget."[246]

"See It:" Tracking

The Stewart Committee which selected Vanguard to be the US's IGY satellite system and Vanguard designers regarded the radio-tracking network as one of the hallmarks of the Vanguard system. Given NRL's reputation in radioelectronics, even von

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[244] Launius, 23.
[245] Long after the last two Vikings were used for Vanguard launcher development, the Vanguard's first stage became the basis for the Thor-Abel and Atlas-Abel's second launch stages and Delta rocket's second stage. In 1960, NASA would launch its first weather satellite on a Thor-Abel launcher. All subsequent TIROS satellites (see Table 6.1 for reference) were launched on Deltas, which in the decades to follow, proved to be one of the most reliable rockets in the US livery.
[246] Newell, *Beyond,* 38

Braun's 1954-1955 Orbiter proposals presumed that the NRL would supply tracking stations, satellite instrumentation, satellite command, and data acquisition for his "no-cost satellite" (implying that all of the resources necessary for his satellite were already available in the DOD).[247]

Von Braun, who had speculated plenty on reconnaissance, meteorological, and communications satellite applications, was still primarily driven by his desire to beat the Soviets into space. Thus, he tended to be somewhat cavalier about tracking methods, confident that optical tracking would be sufficient to prove that the US had indeed placed a satellite in orbit. After the International Scientific Unions and CSAGI had endorsed the contribution of a satellite to the IGY, von Braun redoubled his efforts to gain permission to launch a satellite.

NRL researchers, had spent years speculating on the utility of satellites to perform geophysical experimentation and insisted that a more rigorous tracking capability would be necessary, rather than optical or even the standard radar tracking used for satellites and sounding rockets. Written and published before the first Vanguard proposal, Milton Rosen's "popular" book detailing development of, and experimentation with, the Viking sounding rocket and the transition to the Vanguard precision tracking would be a critical element to the system, rendering satellites viable scientific instruments.

> …the capability of being tracked…will make the satellite an extremely valuable tool. From it we should be able to determine more accurately the size and shape of the earth and the intensity of its gravitational field. This should permit more accurate mapping over large distances and, eventually, more precise all-weather navigation at sea.[248]

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[247] Green and Lomask, 17-20.

[248] Milton Rosen, *The Viking Rocket Story* (New York: Harper Brothers, 1955), 234. In the preface, Rosen thanked Robert Goddard for proof-reading the text.

As of 1955, two options were considered for satellite tracking, originating with or refined by methods for tracking missiles and sounding rockets. These were optical tracking (which in reality relied on optical enhancement provided by cameras) and RADAR interferometry. The classic Azusa tracking radar would necessitate the use of a transmitter too heavy for a satellite that had to be less than 30 pounds. The option of optical tracking proved contentious for a number of reasons. For one, the Navy researchers preferred professional paid observers to the volunteer program proposed by Fred Whipple for the Smithsonian Astrophysical Observatory.[249]

NRL's Minitrack (so named because its transmitter was designed to be significantly lighter than the Azusa hardware) was touted as offering orders of magnitude more and better data than optical tracking. It could remain in operation in inclement weather and total cloud cover and it could operate at any time of the day or night, not just twilight as was necessary for optical tracking.[250] However the Minitrack network was a passive tracking network, meaning satellites had to be instrumented with transmitting hardware in order to be tracked. Also, when on board batteries ran out of power or solar systems failed, optical trackers could continue to chart satellite orbits. Thus, the optical trackers recorded data on the orbits of "silent" satellites long after their batteries had been depleted.

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249 Patrick McCray, *Keep Watching the Skies: the Story of Operation Moonwatch & the Dawn of the Space Age* (Princeton: Princeton University Press, 2008), 80-82.

250 John Mengel, Earth Satellite Project 33.1 Summary, Folder: USNC Member Files; Porter RW: 16 A: Preliminary USNC-IGY Earth Satellite Program & Budget by Project 30 Nov 1956. See also Joseph Kaplan to Alan Waterman, 23 November 1956, letter and enclosed documents prepared by the DOD which cover earth satellite projects. Folder Earth Satellite Program Project 32.7: Naval Research Lab Satellite Environmental Measurements 1956-1961, NAS.

Despite their technical and cultural distinctions, both the optical "Moon Watch" tracking network and Minitrack met US needs for maintaining positive Cold War international relations.[251] Complimenting the primary Minitrack stations was the Mark II Minitrack System, a simplified radio system intended to be used by universities, professional groups, and advanced amateur radio clubs throughout the world. Amateurs across the globe participated in the Moon Watch program for 15 years, well beyond the span of the IGY.[252] The institution of Minitrack under the IGY enabled scientists to place stations across North and South America—sufficient for tracking satellites in equatorial orbit, but not yet polar orbit, which would require a more comprehensive longitudinal network than the north-south fence Minitrack was arranged in.

"Use It:" Computation Center

While the distribution of tracking stations across the Americas set a useful precedent for network expansion in years to follow, and the Moonwatch optical tracking network engaged a variety of amateur astronomers in IGY satellite activities, the computation capabilities of the Vanguard program helped validate the endeavor as a legitimately scientific satellite and not a one-off stunt executed with surplus missile parts.

As was standard practice with scientific computers at the time, the machine was leased from IBM. In a press release, IBM reported on its role supporting the US IGY program. Having taken "18-20 man-years of scientific effort" to develop its programs for

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[251] Minitrack Stations included: Blossom Point, MD, Fort Stewart, GA, Batista Field, Havana, Cuba, Coolidge Field Antigua Island, British West Indies, Rio Hata, Panama, M. Cotopaxi, Quito, Ecuador, Ancon, Lima, Peru, Antofagasta, Chile, Poldehue Military Reservation, Satiago, Chile, Navy Electronics Laboratory, San Diego, CA.

[252] *Globalizing Polar Science: Reconsidering the International Polar and Geophysical Years*, Roger Launius, James Roger Fleming, and David DeVorkin, eds. See Teasel Muir-Harmony's chapter "Tracking Diplomacy: the International Geophyscial Year and American Scientific and Technical Exchange with East Asia" pp. 279-305.

orbital computation and analysis, IBM had produced a computer capable of calculating a satellite's orbit from eight passes over the Minitrack "fence."[253]

Satellites at the time had a useful life of only weeks before the batteries would be depleted—even solar-powered satellites had relatively brief lives of a couple months. Compounded by precious few opportunities to telemeter data from the satellites to ground stations (and with orbital insertion still an imperfect art), the computation center helped data acquisition stations predict the span of time the satellite would pass through their radio horizon and therefore optimize what time they had to communicate with the vehicle.

The first scientific discovery revealed by the satellite computation center (sources do not indicate if this could have been achieved with optical tracking, which it might well) was that the earth was not shaped as predominant scientific thought believed. Rather than bulging at the equator, models of Vanguard Beta's orbit showed curious shifts in its perigee, indicating that the earth mass below the equator was greater than above.[254] As with the Minitrack stations, the Computation Center, too, would transfer to NASA where it would eventually support TIROS operations.

"Use It:" Meteorological Instruments

By 1956, satellites—the only scientific instrument planned for the IGY that had never been used before—had been accepted by at least some within the meteorological community as a "permanent scientific tool from now on."[255] But the precise form and

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[253] IBM information sheet, "The Computer's Role in Satellite Programs," Folder Title Project Vanguard Misc, LEK 3/13/5 NHRC.
[254] IGY General Report Number 21, 551.
[255] Meeting Notes, Sept 20 1956 from Second NAS-NRC Meeting 19 September 1956 Folder ORGANIZATION NAS Committee on Meteorology Advisory 1956, NAS.

function of the IGY proof of concept satellites remained remarkably fluid into 1958 and the 1959 extension of the IGY. Between the spring of 1956 and into 1957, the NAS Technical Panel on Earth Satellites and Meteorological Committee deliberated on which instruments to suggest for IGY meteorological satellite experiments, what order to orbit them in, and which experiments could be launched on the same satellite bus.

USWB's Harry Wexler served on the Technical Panel on Earth Satellites and had long championed the use of satellites to aid in meteorological forecasting. For synoptic meteorologists, the most promising satellite instruments were cloud cover cameras—TV for daytime coverage and infrared (heat) cameras for distinguishing clouds from landmasses on the dark half of the earth. In order to determine the orientation of the satellite and therefore identify precisely what part of the earth was represented in any given image, the Project Director William Stroud of the Army Signal Corps Engineering Lab intended to use the configuration of cells and the pulse width data. (It is worth noting that well into the 1960s, meteorologists struggled to accurately identify the location of cloud masses over the earth).[256]

In September of 1956, a researcher at the University of Wisconsin, Verner Suomi, proposed an instrument to study the earth's heat budget—a research topic much more in line with the NAS Committee on Meteorology than Stroud's cloud cover experiment. Suomi had developed a proposal for an instrument to determine the heat budget of the earth. Attempting to cover his bases, Suomi opened by stating that the instrument would contribute to both "practical (synoptic and forecasting) aspects and basic energy

[256] William Stroud, Earth Satellite Project 32.5 Summary, Folder: USNC Member Files; Porter RW: 16 A: Preliminary USNC-IGY Earth Satellite Program & Budget by Project 30 Nov 1956, NAS.

considerations of the atmosphere." Suomi suggested that imbalances caused by variations in the sun's rays, variations in the earth's reflectivity (albedo) and the transmissivity of the atmosphere may play an important part in climatic variations.[257] In his note, Suomi stipulated that polar orbit would be optimal, undoubtedly because this would provide global coverage of the earth.

RAND meteorologist William Kellogg wrote Wexler in November, indicating that Suomi's was a worthwhile experiment, but with the proposal arriving so late, a development study would have to be undertaken very soon. "As a meteorologist who would like to see these measurements made," Kellogg suggested that the two begin exploring methods of building the equipment in ways that would be compatible with other experiments already underway (as all planned satellites would carry at least one experiment in the payload.)[258]

On 28 November 1956, the Meteorological Committee expressed clear support for Suomi's Earth Radiation Budget experiment as first priority and a television camera cloud cover experiment as a second choice. Given the long lead time on satellite instrumentation, testing, and construction, it was not surprising that a year later, on 3 November 1957, Harry Wexler wrote USWB Chief Reichelderfer to inform him that the IGY Earth Satellite Panel would meet to discuss which instrument (Stroud's cloud cover experiment or Suomi's ERB experiment) to promote for a satellite. Allowing that both

[257] From J. G. Reid to Members of the Working Group on Internal Instrumentation, TPESP 29 October, 1956. The cover letter indicates that Suomi submitted the proposal to Wexler who then forwarded it to the Committee. Wexler had orally introduced this idea at the last Technical Panel meeting called "Proposal for Measuring Energy Budget of the Earth from and Earth Satellite." Box 8, Folder General Correspondence 1956, Wexler Papers.

[258] William Kellogg to Harry Wexler, 15 November 1956, Box 8, Folder General Correspondence 1956, Wexler Papers.

experiments were useful, Wexler indicated that the opinion of Sig Fritz and himself was that the ERB "is needed for the overall global energy picture and might contribute to such practical matters as anticipating changes in global wind regime."[259] Nevertheless, the Technical Panel preferred Stroud's instrument in part, because it seemed a more reliable system.[260] In Stroud's own words, Suomi's "experiment was a better experiment; it gave more quantitative information; but our experiment was in a better state of readiness."[261]

Ultimately, the Earth Radiation Budget won out as being the US's top priority, but due to the expanded launch manifest following the inclusion of the Explorer satellites, both Stroud and Suomi's instruments were certain to be placed in orbit.[262] Instruments from both Stroud and Suomi would also be incorporated on the ARPA plans for post-IGY meteorological satellites and NASA plans for meteorological satellites.[263]

Dual Use Systems

It was no secret that data and proceedings resulting from the IGY could be used the world over for military or non-military purposes. While there were likely formalities such as fees or membership dues to scientific organizations, these resources were in principle available to all participating countries. Armed services just as well as academic institutions, national weather services, and businesses could use IGY information.

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[259] Harry Wexler to Francis Reichelderfer, "Items likely to come up during my absence November 3, 1957 to ? [sic] 1958" October 22, 1957, Box 8, Wexler Papers.
[260] Granted, much of this reliability was due to the fact that defense communities had been analyzing methods for orbiting a reconnaissance camera since the 1940s.
[261] Interview of William Stroud by Eugene Emme, 21 September 1973, Folder 002238 Stroud, William Interview, NHRC, 84.
[262]NAS Report on the US Program for the IGY General Report Number 21, November 1965,556. See Table 1.2.
[263] See Chapter Five.

Embedded within scientifically-relevant acts of collaboration were often seemingly inconsistent compromises favoring national defense over transparency. For instance, during the course of Vanguard operations, Minitrack stations outside the US followed strict visitors' hours and were from time to time shut down to visitors during select operations. The Army Corps of Engineers, however, insisted that the periods of exclusion were "kept as short as possible and frank explanation was made," and even went so far as to advise that these practices were "highly recommended for good public relations." [264]

Hardware and facilities developed with IGY funds were also often dual use in nature. Data retrieved from the Minitrack network on the shape and magnetic field of the earth could be used to improve the accuracy of intercontinental ballistic missiles as well as predict orbital variation in satellites. The techniques honed on Minitrack led directly the US's Space Surveillance System. Whereas Minitrack could not track non-radiating satellites (such as a satellite with a dead transmitter battery or the third stage casing of launchers that tend to orbit with the satellite before re-entry or an ICBM), the Space Surveillance System could use radio waves to "illuminate" non-radiating bodies.[265] By epistemically "flipping" the Space Surveillance network upside down, putting the atomic clocks on multiple satellites and transmitting exact measurements of time to persons on

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[264] 6366 A Report on Army Participation in Project Vanguard May 1959
Army Corps of Engineers, 6361 folder Title Project Vanguard Misc
LEK 3/13/5

[265] Louis Gebhard, *Evolution of Radio-Electronics and Contributions of the Naval Research Laboratory NRL Report 7600* (Washington, DC: NRL), 407-412.

the ground, Richard Easton devised a critical element for the Timation satellites, which were integrated with Air Force plans to form the first generation of GPS satellites.[266]

As for the meteorological instrumentation, while the climatological instruments were of less interest to the armed services, the Navy, Army, Air Force, and Strategic Air Command in particular would take great interest in developing and orbiting an operational weather satellite system as soon as feasible.

Looking Ahead: The Vanguard Team | The TIROS Team

David DeVorkin reports that by 1956, the UARRP had established a community of workers who "placed themselves in the dual role of contributors to science and inventors of a new way to conduct science." Thus, it is little surprise that in celebrating their tenth anniversary, the Panel members, rather than looking back over a decade of scientific discovery, looked ahead, discussing how to build scientific satellites for the IGY.[267]

Why do the nitty-gritty instances of technical uncertainty, expense, and risks in sounding rocket research matter? Many of these are one-time learning experiences (a la Rosen being sent for a pseudo-apprenticeship at JPL) or "modular" achievements (in that the Viking could be incorporated into Vanguard design). The fact that the USWB never considered going down this road of rocket and satellite exploration—and never *could* have achieved the same economies in R&D as the UARRP members—tells us something about the nature of the Cold War build-up and federal reorganization for "peaceful" space exploration.

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[266] Leo Slater, "From Minitrack to NAVSTAR: The Early Development of the Global Positioning System 1955-1975" *Proceedings of the IEEE Microwave Theory and Techniques Society Symposium for 2011.*
[267] DeVorkin, 342

If Newell, Hagen, and Rosen were approached in 1956 and asked the likelihood that in four years their Vanguard team would be transferring the world's first Television InfraRed Observation Satellite (TIROS) system to their operation, they would have likely deemed it feasible. If William Stroud's research team at the Army Signal Corps Lab were asked the likelihood that they could integrate RCA cameras into an operational satellite system and glean useful cloud images for forecasters, they, too, would have found the prediction likely.

The shock would have been organizational. Satellites were logical extensions of sounding rocket practice, demanding far more thrust and reliability from launch vehicles, tracking stations across at least two continents, and data acquisition through an as-yet unmapped ionosphere. Thus, an *operational scientific satellite system* (emphasis on each of the four words) required resources far beyond the reach of just NRL, the Army Signal Corps Lab, or the entirety of the UARRP.

Participation in the International Geophysical Year demanded considerable funds from the DOD, but it also promised substantial *temporary* backing from the White House and Congress via the NSF. Thus, in the IGY they would operate proof of concept satellite systems intended to establish the precedent of satellite overflight as a scientific activity. Beyond the IGY lay a less certain future.

Threats to the IGY Order: Space Stunts and Spectaculars

On 4 October 1957, the Soviets launched the world's first artificial satellite into space. Although the US had been notified that the launch was imminent, miscommunications led to it being quite a shock to US researchers, elected officials, and the public. For many, this event marks the beginning of the Soviet-American space race that policy and historiography have framed as the core driver to the US space program.[268]

In the fall of 1957, the Army resurrected plans for the Orbiter satellite, to which many Vanguard/IGY researchers remained unwelcoming, but at the very least high-level Navy officials took serious note of. Dated two weeks after Sputnik's launch, one proposal explained: "The propaganda catch-word is 'the moon.'" Therein, the proposal recommended stacking a Vanguard third stage atop a Jupiter C cluster to send a satellite into orbit with an apogee equaling the distance of the moon or to even place a payload on the moon. As with the original Orbiter proposal of 1955, this one, too, recommended taking advantage of Navy tracking capabilities. However in glaring opposition to US IGY policy, the plan recommended "this backup program be conducted on a *completely classified basis* in order to prevent any undue acceleration of the Soviet effort and to make possible reasonable speed in our effort."[269] The plans, calling for a four-pound satellite made no reference to plausible scientific instrumentation, nor any conceivable contributions to the IGY. Instead, its author(s) suggested, "If moral commitments so dictate, an announcement of a planned launching could be made just prior to the scheduled event," presuming the lead time was short enough to preclude a second upstaging by the Soviets.

[268] For more on Sputnik, see Z. Wang, Green and Lomask, McDougall, Launius *Reconsidering Sputnik,* Mieczkowski, and Adams.
[269] Emphasis added. "Subject: the US Satellite Program" From Secretary of Navy to Secretary of Defense, Record Number 902 LEK 1/8/3 NHRC.

In outlining the IGY operating principles, the Secretary of the Navy explained how through transparency of operations the US had set itself up for a one-upping by the Soviets (who had never agreed to give launch warning).

> … in accordance with the spirit of international cooperation, every effort was made to conduct this program in such an open manner that all interested countries were completely aware of all its aspects. Special effort was made to insure that every detail of the proposed scientific experiments was well publicized. Initially, even the scheduled date of the first satellite launching attempt was authoritatively reported as 30 October 1957. The availability of this information provided the Soviet government an ideal framework for conducting a propaganda campaign to prove to the world the spectacular advances of Soviet science and technology…This practically assured the Soviets a major "First" in the eyes of the world.[270]

The Secretary of the Navy, Thomas Gates (who in two years' time would be Secretary of Defense) went on to warn that the US and Soviet scientific satellite experiments were "practically identical" in timing and scientific objectives. In the end, he concluded that "the only rational conclusion that can be drawn from this, considering the pointed effort made by the Soviets to reap full propaganda effect from the initial satellite launching, is that the Soviet program is to make the initial scientific investigation in each of the fields."[271] Indeed, the Secretary of the Navy opined, "The degree of sophistication and the quality of each scientific experiment is of only minor value in terms of its propaganda value. The important propaganda question is 'who was first?'" If the US was to respond effectively to the Soviet threat, they must accelerate the pre-announced satellite manifest, thus trumping the Soviets' secret launch schedule.

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[270] Ibid. Reference A was the SecDef Memo Subj: Technical Program for NSC 5520 (Capability to Launch a Small Scientific Satellite During the IGY).
[271] Ibid.

Perhaps one of the most extreme examples of this race mentality is the Non-Stop, Round-the-World circumpolar flight of a B-52 proposed by Strategic Air Command.[272] AF Director of Research and Development explained that this, the first such circumnavigation of the earth, would "Provide assurance to the free nations of the world" and "remind the Soviet Union and its satellites that the US Air Force has a current operational capability of reaching even the remotest areas of the earth in support of the United States national interests and policies."[273]

Rather than launch an unannounced satellite lacking any scientific instruments, by November 6, the IGY Technical Panel for the Earth Satellite Program had begun discussing the possibility of a second "crash" series of scientific satellites, what were named the ABMA Explorer satellites. With additional satellite vehicles to consider, the committee began rearranging what had been a solely Vanguard launch manifest. Van Allen moved his cosmic ray instrumentation from Vanguard's SLV-2 (essentially its second launch attempt) to Explorer I. In its place would be the Army Signal Corps' meteorology instruments that had been slated for the fourth and final Vanguard satellite. RSRP panel chair Homer Newell pointed out that additional funds would be necessary for the speed-up—no small detail given the financial straits of the IGY satellite program.

As with the Stewart Committee competition between the NRL and ABMA satellite proposals in 1955, NRL representatives emphasized qualitative issues—efficacy of ground support, reliability of instruments, prospects for data reduction. The ABMA

[272] SAC had a stake in this since they were slated to operate the AF reconnaissance satellite and were making moves to be the US's central space agency.
[273] Box 6, Folder "Command—Strategic Air." Thomas White Papers Library of Congress Manuscripts Division, Washington, D.C (Hereafter White Papers).

emphasized how soon their equipment could be in orbit. Precisely one month before the launch pad failure of Vanguard Test Vehicle 3, the IGY TPESP resolved:

> In view of information presented today by the NRL concerning the proposed speed-up of IGY satellite firings, the Panel desires to point out that any such schedule as is now proposed would adversely affect the possibility of completing the *orderly* series of scientific experiments now contemplated.[274]

The resolution continued, cautioning that if by some chance NRL would prove capable of providing the necessary satellite testing and ground support necessary for the Explorer satellite series, "the scientific program would still be jeopardized by vehicular difficulties as well as by problems associated with tracking and telemetering which would inevitably result from the proposed speed-up."[275]

Whereas NRL representatives voiced doubts that they could provide adequate support to Vanguard *and* the Explorer projects—both operating on a crash itinerary—Army Signal Corps Director of Research, H. A. Zahl and researcher, H. K. Ziegler worried about the Signal Corps' and contractors' abilities to launch their meteorological cloud cover experiment months ahead of schedule. Even with "top priority" designation by the Army, Zahl and Ziegler cautioned "although rapid data analysis and presentation is especially desirable…the data evaluation equipment may not be ready until three months after the satellite instrumentation."[276] In the months that followed, many researchers would testify to Congress advising against the long-term efficacy of crash projects and advising that the US government instead invest in methodical plans for fundamental research programs. Noting the limited capacity of labs to accelerate programs in the latter

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[274] Minutes of the Fourteenth Meeting Technical Panel for the Earth Satellite Program, Record Number 15605 NHRC.
[275] Ibid.
[276] Ibid.

stages of development, NRL's Head of the Rocketsonde Branch within the Atmosphere and Astrophysics Division, John Townsend, opined that the most important priority was to make certain that "there is available the fundamental knowledge that only can come from basic research." Townsend continued, contrasting crash projects and propaganda stunts with scientifically (yet still diplomatically) relevant activity, stating:

> I was considerably heartened a few weeks back by the amount of testimony to your committee, and by statements by our scientific leaders in the press, to the effect that one of the most important things for us to do now is to increase our efforts in basic research. However, I have been distressed recently at the decay in such sentiment. It seems to me now that we are talking more of crash production programs or 'stunts' to impress our allies and enemies. [277]

He closed, predicting that US capabilities in missiles and rockets twenty years in the future would be "determined by our efforts in basic research today."[278]

Concluding Thoughts

These post-sputnik days were a formative period for the president and others growing wary of an as-yet-unnamed military-industrial-complex. Looking ahead, to varying degrees, historians have argued that Eisenhower's farewell address cautioning that public policy could "become the captive to the scientific-technological elite" links as much, if not more, to his concerns over the formation of a *policy* elite controlling these resources. Gregory Pascal Zachary allows that the President did have sincere concerns about scientific patronage and an imbalance of power that may threaten his democratic ideals as well as the US economy. However, he suggests that to a degree, Ike was "crying wolf." [279] While he wanted to alert the public to the ominous military-industrial

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[277] Satellite and Missile Programs Hearings, 2131
[278] Ibid.
[279] Author notes from AAAS Talk for the 50th anniversary of Eisenhower's Farewell Address, 18 January, 2011.

circumvention of checks and balances, he offered no concrete indictment against the scientific elites. For several years, the fiscally conservative president had fielded accusations of bomber gaps and missile gaps and a lack of civil defense infrastructure for a fundamentally unwinnable "New Look" war.[280]

James Killian, in his memoirs, refers to the "hard-sell technologists and their sychophants," as being the people who irritated Eisenhower the most. Playing upon the ignorance of the public and the legitimately terrifying prospects of nuclear holocaust, enthusiasts emerged offering spectacular salvation of US prestige through one-off displays of technological capability and the dubious escalation of such saber rattling. Killian cautioned: "We were to be wary of accepting their claims, believing their analyses, and buying their wares."[281] Such spectacles would have proven spectacularly expensive, not simply in terms of taxpayer dollars, but as threats to long-run national and international order. James Killian many years later recalled that the Air Force's case for control over the US space program might have been stronger if the Air Force had "suppressed some of its own special brand of fantasies about space." There, top-ranking officers "freely predicted that the next war would unquestionably be fought with space weapons, and some of the smaller air force fry had visions of space wars and dropping bombs from satellites."[282] Killian, who had served several years on the Army's Scientific Advisory Panel, observed with concern when General Medaris, Commander of ABMA which had launched the US's first satellite, "campaigned with a fierce religious zeal" to

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[280] Evan Thomas, *Ike's Bluff: President Eisenhower's Secret Battle to Save the World*, (New York: Little Brown, 2012).
[281] Killian, 238. Pages 237-239 include Killian's perspective on Eisenhower's farewell address.
[282] Killian, 128.

secure the role as central agency of US space exploration. Medaris believed that military satellites (including manned space stations) would surpass even missiles in tactical utility and thus resisted the formation of a civilian space agency in favor of centering the space effort at the ABMA.

The Navy, too, continued with ambitious plans for the future. The Naval Research Laboratory intended to perform studies into navigation satellites, reconnaissance satellites, electronic intelligence satellites, communication satellites, and sundry geophysical and space research satellites. Unbeknownst to even the Vanguard directors, a group of physicists representing the Naval Ordnance Test Station made plans for a "miniscule donut-shaped" satellite weighing only 2.3 pounds.[283]

A decade after the launch of Sputnik, Vannevar Bush reflected on the "damaging" and "disgraceful" interservice rivalries for missile projects, satellite projects, and ultimately, control over the US space program. As early as 1948 and 1949, he had heard such enthusiasts hyperbolize over the speed, thrift, and efficacy of weapons programs. Bush judged their programs possible but impractical, "officers…were proclaiming loudly that such missiles were just around the corner, that we would have them in a year or two, and that they must be controlled [within their branch of the military]…"[284]

At the 1960 dedication of the Marshall Spaceflight Center (essentially transferring Wernher von Braun's Army Ballistic Missile Agency team from the military to NASA),

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283 Matt Billie and Erika Lishock, *The First Space Race: Launching the World's First Satellites* (College Station: Texas A&M University Press, 2004), 141. Watching the spent third stage from Sputnik track across the sky one night, one of the researchers was alleged to have said, "We ought to be able to do that. We ought to be able to shoot the damn thing down."

284 Zachary, 388 and 481 (note 20).

Eisenhower credited all that Americans had and would accomplish to “unrestrained human talent and energy relentlessly probing for the betterment of humanity” and not the “outgrowth of a soulless, barren technology, nor of a grasping state imperialism.”[285] Walter McDougall asserts that the Huntsville engineers positively were not the “cause of Eisenhower’s distress.” I would posit that Walter McDougall is extremely canny about what he writes and what he leaves between the lines. What of von Braun himself?

The next two chapters illustrate how in spite of the political chaos following the launch of Sputnik, a line of satellite specialists were drawn from the world of classified studies and not just placed in the public sphere, but became integral elements to orderly international science services.

[285] McDougall, 228-229.

CHAPTER FOUR
Seeking Sustainable Resources and US Leadership in Space
November 1957-April 1958

Introduction

NASA's ten-month gestation period from Sputnik to Space Act is well-documented as a Cold War political construct, absolutely attributable to the Sputnik saltation[286] and cries for a US recovery in the Soviet-American space race.[287] While Congress and the Eisenhower White House actually approached post-Sputnik reorganization considering the same handful of options: centralization under a military authority, centralization under the AEC, or centralization under the NACA, Democrats in Congress (Lyndon Johnson central among them) seldom missed an opportunity to criticize Eisenhower for complacency—even senility—in defense in the years leading up to Sputnik. Lyndon Johnson's designs on the 1960 White House led to political posturing in the "Johnson hearings" which fostered a climate of public hysteria over the so-called "missile mess."[288]

Tracing the lineage of the technical systems and precedents in scientific practice from the V-2 Panel to the World Weather Watch, this dissertation sheds light on the subtle manner in which non-elite scientists and middle managers also shaped policy

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[286] *Remembering the Space Age: Proceedings of the 50th Anniversary Conference* Steven Dick (ed), (Washington, D.C.: NASA SP-20008-4703), see Intro and page ix.
[287] McDougall, Logsdon *Congress*, Roger Launius, *NASA: A History of the US Civil Space Program* (Malabar, Florida: Krieger Publishing Company, 1994), 24-35.
[288] McDougall, 142.

discourses.[289] This chapter focuses on what NASA was intended to do, what shortcomings in federal organization it was intended to overcome, and the groundwork laid for the US's eventual leadership WWW organization. Given that so many significant events were happening concurrently, this chapter at times teases out important historic themes, rather than maintaining one chapter-long chronology.

First and foremost, the rocket and satellite R&D community sought sustained programs, not the one-off projects of the Defense Department and the temporary IGY. Research community representatives proposed that basic research in space have a home analogous to the National Science Foundation and the Atomic Energy Commission. This "National Space Establishment" was to be the US's "non-military" program. It was to remain a center for international collaboration. On all these points, Eisenhower eventually assented to his Presidential Science Advisory Committee and the wishes of Congress (who had themselves been influenced by reports, letters, testimony, and studies by Rocket and Satellite Research Panel members).

Between October 1957 and July of 1958, drafts for critical legislation were negotiated, not only institutionalizing the principles of IGY internationalism in a NASA, but giving hopes to the Weather Bureau for a national meteorological satellite system to be managed and operated outside of the DOD. Once the legislative and executive branches reached a consensus on the necessity for and principles of a centralized civilian space agency, lawmakers equipped NASA with the necessary governmental authority to pursue space exploration with the authority of an administration, implicitly garnering

[289] I would contrast the non-elite as being those whose letters were included in testimony, but were not called in person to testify. Those who were not on the PSAC, but (tellingly) went on to hold positions of middle-management power in the NASA.

more power than defense agencies such as the Advanced Research Projects Agency and ABMA.

What factors led to the formation of NASA in the guise it took? Working from the "bottom-up," the Rocket and Satellite Research Panel's (RSRP, formerly UARRP) Committee on the Occupation of Space (COS) began considering the feasibility of a space establishment between September and December 1957.[290] During that time, members reached a tenuous consensus emphasizing the importance of sustainable basic research, preferably in a civilian agency. RSRP members circulated their proposals for a national space establishment under their NAS-IGY credentials.[291] Their reports, proposals, and letters of testimony proved influential to both Congress and the President's Science Advisory Committee.

While RSRP members were eager to protect their professional networks abroad, they were less inclined to remark on public opinion abroad. Instead between February and April 1958, congress, the President's Science Advisory Committee and Vice President Nixon added diplomatic nuance to these scientific justifications, convincing the reticent president that an agency featuring a nonaggressive/nonmilitary posture in space might serve the administration's diplomatic interests.

As the world's first satellite Sputnik captured public imagination and ignited calls for a US recovery in the so-called space race. Two months later, on December 6, the failed launch of the US Vanguard Test Vehicle-3 underscored the US's apparently dire circumstances. In response to Sputnik, Senator Lyndon B. Johnson, chair of the Senate

[290] See Appendix A.
[291] Technical Panel on the Earth Satellite Program, US National Committee for the IGY, NAS, "Research in Outer Space: the Basic Objectives of a Continuing Program of Satellite Research are Outlined," *Science* 127 (11 April 1958), pp. 793-802.

Preparedness Investigation Subcommittee, invited the testimony of leading experts in military procurement, missile research, and upper atmospheric science. Aiding him was congressional researcher, Eilene Galloway. Galloway was an established expert in military preparedness, having authored influential reports on guided missiles in foreign countries and DOD manpower organization in the US. For these individuals, the space race was a thoroughly military enterprise begging the thoughtful reorganization of DOD resources.

The testimony of most scientists and engineers centered on four questions: With respect to missiles and satellites, had there been an adequate use of scientific manpower? Second, it asked that witnesses outline the bottlenecks encountered in research and development work. Third, witnesses were asked to outline bottlenecks that impeded development and production of missiles and satellites. Finally, Congress asked that scientists and engineers outline recommendations for accelerating the development and production of missiles and satellites.

With the first three questions, Congress demonstrated that it was not blindly moving forward with reorganization (referenced in question 4), but sought an intensive review of events and activities past. Sputnik did not precipitate the dawn of the space age; Sputnik had incited the political, scientific, and organizational energies that ended the US's 1945-1957 *ad hoc* and defense-managed space program. This signaled the end of the RSRP's relative autonomy as well as space science's unpredictable sponsorship. Having been promised a space program (and being freed of the piecemeal funding of projects), how would the scientists reach an amenable compromise of interests with Congress and the Eisenhower Administration? A flurry of meetings changed the tenor of congressional preparedness hearings and led eventually to the formation of NASA in a guise very closely resembling the recommendation of the RSRP's Committee on Space.

It is important to note that the initial intent of this congressional investigation was not to divide US resources between military and civilian space programs. Congressional leaders conceived of the space race as being a military undertaking and thus, the January testimony was dominated by talk of centralization under the military and reducing unnecessary duplication of R&D among the armed services in an effort to better compete in the missile and satellite race. Furthermore, subcommittee members demonstrated an extremely limited understanding of the principles under which the IGY—implicitly and explicitly—had been planned.

In the face of a growing Congressional and White House consensus for a centralized DOD-operated US space program, a handful of RSRP members lobbied the Eisenhower Administration, the President's Science Advisory Committee, the Vice President, the AEC, and congressional leaders for the formation of a National Space Establishment independent of the DOD's ARPA for basic research and non-military applications.

Eilene Galloway would credit these IGY scientists with reframing the investigation from military preparedness to the broader scope of national governance and in time, international governance.

> A curious thing came about. Instead of being a problem that was solely national defense where we were really afraid for our security, it became a problem of maintaining peace. It became a problem where the scientists and engineers came up and told us of all the benefits we could derive from using outer space. They

> told us about communications, increasing the benefits of meteorology, all the information to solve [civilian] problems on the Earth.[292]

Whereas congressional leaders had begun their investigation absorbed with solving the problems of Sputnik and the space race, testifying provided scientists and engineers—some of whom had engaged in IGY research and many of whom had contributed solely to military R&D—an opportunity to express their wide range of concerns. Some members of the COS conceived of a federal reorganization that would coordinate military (i.e. ARPA) *and* civilian centers of R&D. Doing so would overcome shortcomings suffered by the RSRP in the *ad hoc* years of 1945-1957 while laying groundwork for the US's position of long-term leadership in the occupation of space.

William Stroud, project manager for Vanguard II's meteorological satellite instrument as well as NASA's follow-on TIROS weather satellites, described how the RSRP explicitly sought programmatic support from Congress for a National Space Establishment (as opposed to the project-by-project funding of space sciences under the armed services). This included permanent facilities, salaried personnel, a constant supply of materials, essentially an organization complete with financing, and logistical capabilities. These demands were shaped by experiences outlined previously in Chapters Two and Three, covering the *ad hoc* years of 1945-1957. During that time, the space science community operated under four formative conditions necessary for understanding the formation of NASA. These included: the desire to augment technical work with basic or knowledge-driven research, the desire for an orderly program as structured by researchers and not in response to political demands, wariness of validating each project

[292] Interview of Eilene Galloway by Rebecca Wright, available at http://www.jsc.nasa.gov/history/oral_histories/NASA_HQ/Herstory/GallowayE/EG_8-7-00.pdf, 4-5.

by its immediate applicability to defense capability, and finally, the desire to maintain open relations with and sustained access to international partners.[293] While DOD sponsors and lab management were not patently opposed to all four of these conditions in all circumstances, these do provide a useful framework for considering the formative experiences of researchers who would soon advise Congress on the formation of a National Space Establishment.

Missile Preparedness Hearings and the Sounding Rocket Research Funding Crisis

As sounding rocket researchers, the UARRP members were the US's *de facto* experts on missiles and satellites. Thus, by the time COS researchers were preparing statements for the 1957-58 Missile and Space Preparedness hearings; they had identified their aim. The RSRP needed sustainable funding, preferably independent of the armed services, but institutionalized and programmatic nevertheless. Leading members of the RSRP were sent letters requesting their written testimony, but Vanguard director, John Hagen and Wernher von Braun were the only two RSRP participants who traveled to the Hill to testify (and von Braun had just joined the RSRP in December 1958). The other fifty-five witnesses called to testify read like the index of a Cold War history book: Edward Teller, Vannevar Bush, James Doolittle, Neil McElroy, Donald Quarles, David Sarnoff, a host of armed services generals, and more.

Newell, Stroud, Townsend, and colleagues, too, had been invited to explain the success of Sputnik and the failings of a system that had produced the Vanguard Test Vehicle-3 explosion, but they were to do so by letter. In their testimony, they used their

[293] These sentiments are evident in documents dating to the UARRP years as well as congressional preparedness subcommittee hearings. They are fleshed out in the preceding two chapters, but summarized here.

experience on the UARRP to illustrate not only the complexity of their procurement and operational systems, but the dire state of DOD funding for basic research over the past few years.

Since the 1940s, members of the UARRP had attempted to strike a sound balance between meeting national security needs, but at the same time investing sufficient resources in scientifically-relevant exploration of the upper atmosphere. Chapter Two has outlined the various "surpluses" supplementing Panel activities in the late 1940s and early 1950s—enemy hardware captured during the war, surplus US hardware left over from war research, personnel who federal labs campaigned to keep on staff despite the war's end, even surplus ideas—leads for postwar basic research and avenues that could not be explored at the expense of crash engineering projects necessary to support the war effort.

Over time these researchers justified and re-justified rocketborne basic research activities to their DOD sponsors—themselves facing substantial budget cuts. In the early days various "surpluses" provided justification for performing space R&D, but researchers had locked-in to an upward ratchet of resource consumption. Whereas the V-2s had provided a relatively "free ride" for scientific instruments in the immediate postwar years, by the time the armed services began costly development and testing of follow-on sounding rockets, 1947 military reorganization forming the DOD actually muddied the waters of missile development policy and heightened latent animosities among the services.

In their testimonies, UARRP participants explained how they had honed creative accounting methods to sustain their programs, such as the drawing off of lab overhead to cover expenses when the Iris sounding rocket funding was cut or partnering between Army and Navy to save the Arcon sounding rocket. The Viking sounding rocket (unsuccessfully marketed by Newell as a test vehicle for ballistic missile research) survived only because of the influx of funds provided by the IGY: in 1955, Viking became the first and second stage of the Vanguard launch vehicle.[294] Sounding rocket budgets declined and entire projects were cancelled.

Years later when lecturing students at the Industrial College of the Armed Forces, Lloyd Berkner was asked if the US had acted upon 1945-1947 satellite proposals and invested all resources necessary, how soon the US might have launched a satellite. Knowing full well that the von Braun team at ABMA had stood prepared to launch a minimum orbiter years before Sputnik, Berkner responded with a pithy critique of the US rocket R&D. "[W]e have lost a lot by our failure to continuously support our rocket activity," he said, contrasting the US with the German V-2 R&D teams who "got going" in 1928 and sustained research into the 1940s. Berkner pointed out that the US had not been supportive of rocketry as soon or with the same degree of commitment. "All our money was pulled away in 1952 and our people all dispersed. We got going again, and again our money was pulled away in 1954 and all our people dispersed." Berkner suggested that IGY money provided in 1955 was how the sounding rocket community "finally got to stay in the business."[295]

Indeed, IGY planning provided an important windfall to sounding rocket exploration, promising a total of $14.8M to UARRP members, but again, raising the

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[294] Satellite and Missile Programs Hearings, 368.

[295] Lloyd Berkner, "International Geophysical Year," transcript of 27 January 1959 lecture, Publication No. L59-97, Industrial Collage of the Armed Forces, Washington, DC.

obligations between researchers and sponsors. Further complicating matters, the National Academies of Sciences and Department of Defense at times differed on their respective funding responsibilities. In April of 1955, the Eisenhower Administration instituted the noninterference clause for IGY research and funding responsibilities—demanding that IGY participation under no circumstances draw personnel or other resources away from ICBM development. This gave DOD sponsors further leverage when they were forced to cut funding for IGY participation. The IGY sounding rocket program was very nearly stillborn.

Before the official start of the International Geophysical Year, the Air Force – University of Michigan research team progress reports indicated dire circumstances. In addition to the Air Force reducing in-house funds and personnel, two contracts would run out of funds before the end of the fiscal year. The Principal Investigator noted five contributing factors: the AF and university had underestimated cost of operations, severe limitations to AF funds "precluded any safety factor," unexpected and large amounts of overtime, a requirement that all funds be committed by the close of the last calendar year, and a "general deficiency of contractual funds at ARDC after 1 January 1957.[296]

To the Weather Bureau, these cuts in DOD spending were a welcomed opportunity. Following an August 1957 freeze in AF R&D funding and a 10% cut in R&D funds for the *whole* DOD, the AF Geophysics Research Division (GRD) cancelled two contracts at New York University, two at Texas A&M, and one at the University of Wisconsin. Wexler prompted Reichelderfer to "seize leadership in the meteorological

[296] Air Force Cambridge Research Center Geophysics Research Directorate Quarterly Progress Report No. 3 1 April 1957. Folder "Rocketry: Air Force Cambridge Research Ctr Project 10.5, 1956-1961, NAS.

research and development field in accordance with your hopes expressed over the last few years." Wexler was confident that with minimal investment the USWB could keep some of the projects funded through the end of the fiscal year.

Soon thereafter Fred Whipple, chair of the IGY Technical Panel on Rocketry received a letter from Homer Newell, Chair of the Special Committee on the IGY. In it, Newell cautioned that the overall budgetary situation in the DOD looked grim. All DOD agencies participating in the IGY were deeply concerned about widespread shortages in the "internal funds" required for the IGY science program. The situation at the University of Michigan was "extremely desperate," as the UARRP stood to lose two upper air research groups.[297]

Sources do not indicate if the RSRP considered approaching the USWB for assistance. Ultimately, Newell requested that Whipple's Technical Panel on Rocketry urge the IGY National Committee "approach the appropriate DOD areas immediately and obtain positive assurance that DOD will meet its scientific commitments to the US-IGY Rocket Programs." In the months that followed, mid-level managers at DOD labs exchanged similar narratives of procurement complications and cut funding. The Army's Signal Corps Lab was reported as being "desperate for operating funds." The Air Force was $121,000 behind on just two contracts and at least one Navy rocket program was facing contractor overruns.[298] The launch of Sputnik brought a public uproar and cries for

[297] Newell to Fred Whipple, Sept 13, 1957, Record Group 181, Box 3, Folder 2, Rocket-Sonde Research Secgtion (Naval Research Laboratory) V-2 Panel Papers, National Air and Space Museum, Smithsonian Institution National Air and Space Archives (hereafter Smithsonian).
[298] File Rocketry Naval Research Lab 1955-1959, NAS.

an accelerated IGY program, but no immediate financial respite for the *rocketsonde* groups who were performing rocket and satellite R&D.

Rocket procurement was just one element of coordination suffering under the IGY coalition. Even after Sputnik, RSRP sponsors could not (or would not) allocate funds for the group to order post-IGY equipment. Eighteen-month and two-year lead times on rockets demanded it.[299] In his testimony, William Stroud, responsible for the Army Signal Corps' satellite cloud-cover experiment explained that his lab's satellite research group and upper atmosphere rocket research program existed solely because of the infusion of IGY moneys. Half his officers and enlisted men were temporarily assigned and sixty percent of the civilians on temporary loan until Vanguard was complete.[300] The Naval Research Lab's Jack Townsend, Head of the *Rocket Sonde* Branch within the Atmospheric & Astrophysics Division, offered almost precisely the same observation, stating that the NRL program was in "dire straights" and unable to secure funds for post-IGY research. Echoing a familiar sentiment, he, too, speculated that his branch would be "out of business" were it not for IGY.[301] If such dismal funding trends continued, December 1958 would signal not only the end of the 18-month IGY, but perhaps even the end of consequential coordinated research among RSRP members.

RSRP Politicking

How did a nonmilitary space program emerge from post-Sputnik America? The answer is complicated by the many motivations of individuals and refracted by a flurry of meetings, hearings, and general correspondence taking place over the course of

[299] Satellite and Missile Hearings, 2129.
[300] Satellite and Missile Hearings, 2125.
[301] Ibid, 2129.

approximately eight months. Individual-by-individual, motivations ranged broadly and changed dramatically as the Congress and the Eisenhower Administration (and countless derivatives thereof) consulted scientists, engineers, and representatives of the armed services on how best to reorganize resources.

In fall of 1957 and winter 1958, the Rocket and Satellite Research Panel met regularly in the interest of analyzing the possibilities of a National Space Establishment (NSE)—even as the representatives labored on their respective IGY projects Explorer and Vanguard (see Appendix A for a list of meetings). In the winter and spring of 1958, Kellogg reported that some other "big guns" began to join the COS. These included James van Allen, Wernher von Braun, William Pickering, John Townsend, and several others, who in large part had been encouraged by IGY's Joseph Kaplan in an effort to bring more proponents to the cause of a civilian space agency.

William Stroud of the Signal Corps took credit for finally swaying Wernher von Braun. Stroud had for years been working in collaboration with von Braun, Ernst Stuhlinger, and others from the ABMA and more than once had functioned as an informal liaison between the IGY participants and the missile-oriented ABMA team.[302] Von Braun attended the 19 December 1957 RSRP meeting (thirteen days after the

[302] In particular, Stuhlinger had asked Stroud to communicate the capability of his team to launch a perfunctory and essentially payload-less satellite. "After Sputnik...Stuhlinger urged me to use my influence with the Navy people, with Newell in particular, to let them know what was going on in the Army, and particularly what was going on down at ABMA." Stroud presumes that Rosen and all did not know the "state of readiness of the Army, of VB's crew" Interview of William Stroud by Eugene Emme, 21 September 1973, Folder 002238 Stroud, William Interview, NHRC, 42.

Vanguard TV-3 failure) where "we spent hours trying to convince von Braun to back the civilian approach. He wanted to go military."[303]

On the 14 December 1957 von Braun had carefully crafted his response to congressional testimony. Rather than refer to a National Space Establishment (the terminology used by the COS for their proposed civilian space agency on a document he had signed), von Braun stated:

> …the outer space physical research program which is presently going on under the auspices of the IGY, should most certainly be continued after the IGY is over. But right now there is no agency in this country which is really responsible for its continuation…The continuation of this research program would, in my opinion, be a logical assignment to the National Space Agency.[304]

Hedging his bets, von Braun did not want to yet go on the record in favor of a civilian program. However he did opt to distinguish such a National Space Agency by its "continuation of a research program." Historian Michael Neufeld described von Braun's "public flexibility" regarding a space agency. In Congress, he endorsed the notion of a centralized space agency, under either civilian or military leadership (so long as it managed both civil and military space exploration and remained under "one man"—himself and General Medaris being the most speculated candidates).[305] Von Braun also signed the American Rocket Society's proposal for a space agency and in time would attend COS meetings and (at least ostensibly) support COS campaigning for a civilian space program. In addition to this, von Braun remained ever concerned with the US's domination in space. In Congress, he interpreted Soviet policy in space as being "'If we

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[303] Ibid.
[304] Satellite and Missile Hearings, 579-632.
[305] Neufeld, 317.

want to control this planet, we have to control the space around it.'"[306] In addition to his engagements with the IGY scientists and the American Rocket Society, von Braun authored a classified proposal of his own "A National Integrated Missile and Space Development Program." Therein he proposed a $1.5 billion dollar budget (von Braun undoubtedly meant per year, given the COS budget of $1B/yr) to support the use of Army launch vehicles for heavier scientific satellites, moon probes, one- and two-man spacecraft, and by 1965 a twenty-person space station.[307]

Whereas Von Braun was covering all possible bases with space agency proposals, military and civil, it was while serving on the NACA (National Advisory Committee on Aeronautics) Stever Space exploration committee that he settled upon endorsing NACA as the center of the new space agency—viewed as a non-military center of basic research into aeronautics.[308] In the meantime, he maintained a presence with RSRP colleagues, providing them vital access to the White House. Thus, on 22 January 1958, Von Braun, Newell, Pickering, Ehricke, and Stroud met with the Vice President Nixon. Newell gave opening comments based on COS proposal and found the VP not only a willing listener but active supporter of the ramifications of international cooperation, providing leads and contacts to the AEC and the US Information Agency. [309]

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[306] Neufeld, 317
[307] Neufeld, 318.
[308] Interview of William Stroud by Eugene Emme, 21 September 1973, Folder 002238 Stroud, William Interview, NHRC, The Stever Committee was put together by NACA after the launch of Sputnik to study spaceflight. See Alex Rolland, *Model Research: The National Advisory Committee for Aeronautics 1915-1958* (Washington, D.C.: NASA SP-4103), 458.
[309] Stroud credits Von Braun for their meeting with Nixon, at which the vice president provided the COS members with connections to persons in the US Information Agency and AEC.

US Information Agency Director George Allen and staff proved supportive of the COS, "greatly interested" and appreciative of not only the scientific and technological significance of a NSE, but also its prospective role in diplomacy. While these self-appointed representatives of the scientific community cannot be identified as policymakers in the sense that they determined NASA's precise function or the details of its form, their role as advisors provides a critical linkage for understanding the complicated origins of the US's nonmilitary space program and how a growing number of congressional and White House officials began to recognize their stakes in the (re)organization of space R&D.

Newell, Stroud, Townsend, and Cummings attended back-to-back meetings with the AEC, US Information Agency, and Congressional committees. That morning they met with the five AEC commissioners including Strauss. Newell was sick with a cold and NRL's Jack Townsend had to do the talking.[310] RSRP minutes indicate that the meeting was wholly "unproductive." This was due in small part to the fact that Newell shocked AEC members, explaining that the proposed space program would likely require as much as a billion dollars a year, rivaling the AEC's budget.[311] Signal Corps' Stroud, was more candid, indicating that AEC commissioners were interested only in "taking over." "They wanted the job," he explained. "The science, they didn't understand" and by implication, were not concerned with.[312] At this point, the RSRP COS activities attempting to garner support for a non-military center of space R&D were quite daring, for if they backfired, space R8&D— and their jobs—would remain under military management.

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[310] Interview of William Stroud by Eugene Emme, 21 September 1973, Folder 002238 Stroud, William Interview, NHRC, 60-61.
[311] Newell *Beyond the Atmosphere*, 47.
[312] Stroud Interview, 62.

The National Advisory Committee on Aeronautics (NACA), too, was under consideration as a home for the space program, but many worried that the R&D organization had become too "ingrown," it was described as subject to the desires of military and industrial customers and that "science carried little weight." One historian described it as a "captive of the military-industrial complex.[313] NACA's Hugh Dryden indicated his sensitivity to these concerns, courting the Institute of Aeronautical Sciences in January of 1958. Summarizing the situation in Congress and the White House, he stated that the essential necessity for a "new civilian space agency is plain. The scientific community, understandably, is worried about the possibility that extremely important non-military aspects of space technology would be submerged or perhaps even lost if included as a mere adjunct to the military program."[314] There remained the risk that a civilian agency may be stood up on paper as independent of the armed services, but like NACA, still allow its research agenda to be dictated by the armed services.

Civilian Applications and Fundamental Research as Congressional Concerns

Winter congressional testimony, proposals in periodicals for a National Space Establishment, as well as the actual COS-NSE proposals indicate that most representatives of the space science community tended to be unwilling to speculate on the significance of worldwide public opinion or to weigh in on the space for peace rhetoric. Instead, they focused on the necessity of their national space establishment as a home for basic research and/or development of non-military technologies. Rather than be constrained to demanding lists and deadlines of space spectaculars, select representatives

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[313] Rolland, 303.
[314] Hugh, Director of National Advisory Committee for Aeronautics, "Space Technology and the NACA" Luncheon meeting of the Aeronautical Sciences New York, NY, 27 January, 1958 File NACA Documents, 1958, RN 15856, NHRC.

of the scientific community advocated a methodical and sustainable program of scientific research. Implicit to the joint American Rocket Society-Technical Panel on Earth Satellite Program-RSRP proposal (released publicly in January and supplied to Congress and the PSAC) was a civilian managed civilian agency, removing select researchers from ARPA authority and the risk of centralization under Army Ballistic Missile Agency or the Air Force. Actor terms centering on basic research remained a constant element defining the agency's mission, with varying prognostications of civilian weather and communications services.

Testimony gathered over the winter shaped congressional discourses into the spring. William Pickering, Director of the Jet Propulsion Laboratory advised against: "crash missile programs," and instead, advocated maintenance of an "orderly progression from research to production." Concerning the notion of a centralized national space program, he suggested a "national program for the exploration of space, under scientific direction but closely integrated with the military hardware programs."[315]

The Army Signal Corps' William Stroud stated: "It is not only a matter of accelerating certain weapons programs such as the Jupiter, Thor, Atlas, Polaris, and possibly the Titan system, which, I believe, should be done." In the interest of a more balanced space program, he suggested that, "simultaneously and immediately we must prepare for the long-range challenge; namely, the exploration and habitation of outer space. This is not a military problem."[316] Instead, he called for a "national project, civilian managed, scientific in concept and spirit with a sufficient budget, independent of the DOD with the responsibility, authority, and accountability for the mission of carrying

[315] Satellites and Missiles Hearing, 2094.
[316] Satellites and Missiles Hearing, 2126.

out the *scientific exploration* of outer space." This and only this would provide the US with the "scientific and technological strength necessary for its survival."[317]

William Kellogg, RAND's head of Geophysics in the Engineering Division who authored the first papers speculating on the viability of meteorological satellite instruments, enclosed the COS's proposal for an NSE in his testimony and quoted it at length:

> Space research will contribute enormously to the educational, cultural, and intellectual character of the people of the United States and of the world…There will be a rich and continuing harvest of important practical applications as the work proceeds. Some of these can already be foreseen—reliable short-term and long-term meteorological forecasts, with all the agricultural and commercial advantages that these imply; rapid, long-range radio communications of great capacity and reliability; aids to navigation and to long-range surveying; television relays; new medical and biological knowledge, etc. And these will only be the beginning. *Many of these applications will be of military value; but their greater value will be to the civilian community at large…."*[318]

Hand-in-glove with these calls for a sustained program of basic research were judgments of the Defense Department as constraining technological developments to military applications. Appealing at times to the principles of the Atomic Energy Commission and at times the National Science Foundation as institutional models, they hearkened to the rationale that basic science was best managed by civilians, free from undue military influence or the constraints of classification.

ARPA Formation & Resistance to a Wholly Military Space Program

In the first week of February 1958, the Congress passed US Public Law 85-326, instituting the Advanced Research Project Agency and consolidating all US space projects under ARPA. Between the passage of the law in April and the formal "opening"

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[317] Emphasis added, ibid.
[318] Emphasis added, ibid, 2118.

of ARPA in April, congressmen, and central among them, Senator Lyndon Johnson and Representative John W. McCormick began campaigning for the institution of a civilian space program. By this time dozens of US institutions had identified some stake in satellites and/or suborbital space research. These included multiple research facilities among all three armed services, university researchers, the Weather Bureau, the National Advisory Committee on Aeronautics (NACA), the Atomic Energy Commission, along with their industrial partners that took the initiative to fund their own research into satellite instruments, launchers, and support systems. Among these many interest groups, the main contenders for control of the *national* space program included: ARPA (as final home), NACA, AEC and to a less-seriously considered, the ABMA and Air Force.

Congressional hearings drew unprecedented attention to the once-ignored missile and satellite programs. Lawmakers sought a long-term fix for what they and many in the science community perceived to be inadequately organized resources. Given the fact that the armed services had pursued space exploration for so many years *ad hoc*, policymakers deliberated over the proper placement of several projects. These projects included: the AF Discoverer satellites (cover for the Corona reconnaissance satellite), NRL's IGY satellite project Vanguard, the ABMA's Explorer satellite series instated after the success of Sputnik and launch pad failure of Vanguard, as well as drawing board plans for navigation satellites, reconnaissance satellites, meteorological and communications satellites among the Army, Navy, and Air Force.

Even before ARPA was in formal operation, many viewed it as a stopgap measure while Congress and the White House determined what to do about non-military applications and fundamental research. Preferring to expand a pre-existing center of federal R&D, the two most serious proposals debated housing civil space under the Atomic Energy Commission or the National Advisory Committee for Aeronautics. While Congress deliberated, President Eisenhower consulted with the Presidential Science Advisory Committee (PSAC).

Consensus emerged in the PSAC supporting NACA as the seedbed for the civil space program. Some such as the Secretary of Defense Neil McElroy and Deputy Secretary of Defense Donald Quarles warmed to NACA's history of fruitful DOD cooperation (for indeed, NASA and the DOD would have to negotiate and share a great deal of common ground in the years to come).[319] COS members tended to prefer NACA over the AEC for a number of reasons. For one, there was the perception that AEC officials were actively pursuing space technologies for the bureaucratic clout. On 14 February 1958, Wernher Von Braun testified to Congress indicating that the aviation industry favored NACA over the AEC.[320]

That March, Lloyd Berkner called for a civilian space program in the *Bulletin of Atomic Scientists*. Considering both the threats and the promises of space exploration as an analog to atomic energy, he suggested that the US had faced a similar decision when it settled on the Atomic Energy Commission. The AEC, he explained, provided a "mechanism through which 'atoms for peace' and other friendly international activities

[319] See Z. Wang 88-97, Rolland 290-303, McDougall 168-176.
[320] Von Braun served on the NACA's Special Committee on Space Technology (Stever Committee) alongside Dryden, Stever, Silverstein, van Allen, Hoffman, Hyatt, Gilruth, Lovelave, and Ridemour.

sparked by the atom can aid in breaking down international tensions."[321] Berkner's BAS piece was just one of several opinions recorded from influential scientists. Eilene Galloway collected these in her study "Compilation of Materials on Space and Astronautics No. 3 Organization of Space Activities of the Federal Government: Selected Statements for the Special Committee on Space and Astronautics."[322] Within the selected statements Galloway cited Lloyd Berkner, James van Allen, George Sutton (President of the American Rocket Society), [323]

That April, the NAS's TPESP members outlined their consensus for a National Space Establishment in the journal *Science.* In their article, "Research in Outer Space" the members stressed that while there would be many "benefits of a practical nature," the fundamental objective of a long-term space exploration program, must be the "quest for knowledge" about the solar system, universe, and beyond.[324] The researchers envisioned

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[321] Reference from Galloway papers, Lloyd V. Berkner, "Man's Space Satellites," *Bulletin of the Atomic Scientists* XIV (March 1958), 104.

[322] The Galloway Papers had not yet been arranged when I visited. Many papers and books were packed in boxes without folders. My notes indicate that this was in the Folder "Atomic Energy."

[323] Ibid.

[324] Members were identified in a footnote: R. W. Porter (chair), G. M. Clemence, Michael Ference, Jr., Joseph Kaplan, Homer E. Newell, Jr. Hugh Odishaw, W. H. Pickering, J. G. Reid (secretary), a. H. Shapely, Athelstan F. Spilhaus, James A. van Allen (chair), Fred L. Whipple. *Working Group on Internal Instrumentation:* James van Allen (chair), Leroy R. Alldredge, Michael Ference, Jr. Herbert Friedman, William Kellogg, Hugh Odishaw, R. W. Porter, O. H. Schmitt, Lyman Spitzer, Jr. *Working Group on Tracking and Computation:* W. H. Pickering (chair), G. M. Clemence, W. A. Heiskanen, J. T. Mengel, J. A. O'Keef, J. E. Steakley, Fred L. Whipple. *Working Group on Satellite Ionospheric Measurements:* A. H. Shapely (chair), W. Berning, George Grammer, C. Gordon Little, Wolfgang Pfister, J. C. Seddon, Ralph J. Slutz, G. W. Swenson, Jr. O. G. Villard, Jr., A. H. Waynick, H. W. Wells. The footnote continues stating that the *Science* proposal was based on an earlier report that explored a narrower scope of experimental activities. This had been prepared by William Kellogg with the TPESP and Working Group on Internal

a wide variety of pursuits being achieved in an explicitly incremental fashion by a non-military organization. These pursuits included: sounding rockets, earth satellites, lunar-, planetary-, interplanetary- probes, and ultimately human spaceflight.[325] Due to White House opinion (with PSAC influence), congressional testimony, and public opinion, that month Congress gradually transitioned from notions of a lost "space race" to long-term solutions for US space exploration and basic research. Reinforcing a sentiment stated earlier in this chapter and expanding upon it, National Defense Analyst Galloway recalled:

> The initial assumption was that we faced a military problem. By Jan. 23, 1958 [the close of the first round of testimony], we had recorded 1,377 pages of testimony by preparedness experts. But it was the testimony of scientists and engineers from many sectors, including the International Geophysical Year that helped change our perception of the problem. These witnesses discussed the important practical applications of space… including long-term meteorological forecasts and rapid long-range radio communications.[326]

The researchers earnest call for a basic science research program mated neatly with Congress's (particularly Representative John McCormack and Senator Johnson's) interest in a peaceful/nonmilitary space program and the necessity of this agency for garnering international goodwill, at the same time securing US leadership in space. Galloway (who for decades would carry unofficial mantles such as "grand dame of space" and "grand matriarch of space law") attributed the unanticipated shift in tenor to the testimony from IGY scientists and engineers: "Use of space was not confined to

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Instrumentation. "Research in Outer Space: The basic objectives of a continuing program of satellite research are outlined," *Science* 127 (April 11, 1958), pp793-802.

[325] Briefly in the introduction and in the last few hundred words the article addressed the possibility of human spaceflight, judging the activity to be unjustifiable for the time being, the authors took it as an, "article of faith" that in time humans "would be required to do the job of cosmic exploration personally—and furthermore, that he will *want* to do the job himself, whether required or not."p. 802

[326] Emphasis added, Galloway Interview.

military activities. It was remarkable that this possibility became evident so soon after Sputnik and its significance cannot be understated."[327] Galloway's formal and informal influence over legislation increased gradually. She continued stating:

> …the scientific community that had been working on the IGY studying the whole earth including outer space, the Nation States, and the United Nations were three that combined *to make it possible for us to emphasize peace rather than war.* We would be prepared for national defense, but we were also going to use outer space for peaceful purposes.[328]

As spokesmen and representatives, if not the material developers of emerging space technologies, the expertise of the scientific community validated lawmaker's faith that the US could oversee the development of at the very least meteorological and communications satellites for the US public. Developing civilian technologies for non-military purposes served a spectrum of practical and diplomatic needs. For some, this was a logical extension of the space race into Cold War diplomatic posturing. For instance, PSAC Chair Nelson Rockefeller and Johns Hopkins President Milton Eisenhower stressed the importance of a civil space program in world opinion, stating, "The psychological impact of the Russian satellites suggests that the US cannot afford to have a dangerous rival outdo it in a field which has so firmly caught, and is likely to continue to hold, the imagination of all mankind."[329]

The trajectory of Galloway's career (from defense analyst to US representative on the UN Committee on Peaceful Uses of Outer Space) plot important events and ideas leading to the formation of NASA in the guise that it took. Galloway identified herself as a National Security/International Relations analyst. She began her career in the

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[327] Ibid, emphasis added.
[328]Ibid, emphasis added, 5.
[329]Mcdougall, 171

Congressional Research Service, but in 1947 and 1953-54 was on loan to the Senate for work on Armed Services reorganizations. Thus, she was a logical choice in 1957 when she served on the Senate Preparedness Investigating Subcommittee of the Senate Armed Services Committee during hearings chaired by Johnson on the Missile-Satellite Situation, beginning in November 1957. During this time she also worked for the Chairman, Senator Richard B. Russell on the impact on the US of the Soviet Union being the first to send a satellite in orbit. The following year she was appointed as Special Consultant by Johnson to the Senate Special Committee on Space and Astronautics to work on NASA legislation. She also assisted John McCormack, Chair of the House Select Committee on Astronautics and Space Exploration. She assisted Johnson in writing the speech he delivered at the United Nations, November 1958, at the request of President Eisenhower, on the peaceful uses of outer space. In 1959, Galloway was on loan from the CRS as Appointed Special Consultant to the Senate Committee on Aeronautical and Space Sciences (1959-1975). During that time she wrote and edited a number of Senate documents on international organization and cooperation in outer space, including space law. Beginning in 1958, she was a member on the US Board of Directors of the International Institute of Space Law for the International Astronautical Federation. She served on the American Rocket Society Space Law and Sociology Committee from 1959 to 1963. Her career continued well into the 1980s with work in the National Academies of Sciences and Engineering, the State Department, George Washington Law School, the International Astronomical Federation, and the Committee on the Peaceful Uses of Outer Space.

On 25 July, representative McCormack passed a unanimous house bill in favor of preserving the use of outer space for research, development, and exploration. "We want to dedicate the use of outer space to peace and cooperate with the world in this regard."[330] Significantly, the bill went on to note that if the Soviet Union were to develop space capabilities "alone," that the US and free world would face the "terrible" possibility of an "ultimatum for surrender." The formation of NASA stood at a complex intersection of state-level posturing, scientific practice, and federal accountability to taxpayers and voters.

Internationalism

Questions of sustainability were not only couched in terms of resource allocation, but policies conducive to long-term international coordination. In particular, researchers worried about maintaining access to partner nations' data, human resources, hardware, and facilities in a diplomatically palatable fashion. Here the principles of "nonmilitary" or "basic" research provided the key to international exchange. Like the IGY, NASA functioned at once as a place within the US bureaucracy to conduct sounding rocket and satellite R&D as well as a nexus of experts tasked with maintaining US leadership in space and the upper atmosphere.

Paradoxically, the climate of crisis following Sputnik I's launch at once threatened the orderly and scientifically-relevant attributes of the IGY satellite program even as it galvanized federal opinion that *something* must be done to ensure US leadership in space. Between the fall of 1957 and summer 1958, the notion of a National

[330] On 16 July MCormack gets this passed unanimously in the House. "Just as surely as we fail to make a real effort to develop these new scientific means across a broad front of research, development, and exploration, a terrible disaster will await us. We want to dedicate the use of outer space to peace and cooperate with the world in this regard."

Space Establishment remained quite up in the air—perhaps under DOD leadership, perhaps under civilian leadership. Meantime, policymakers considered a range of "space stunts" and crash programs that may or may not salvage US prestige abroad. Federal reorganization in response to Sputnik and the Vanguard TV-3 launch failure certainly begged an increase of financial support and acceleration of launch schedules, but a small minority of congressional witnesses insisted on institutionalizing IGY doctrines of transparency and inclusivity in a permanent space agency as well. These doctrines of transparency were evident in the earliest days of IGY planning. As early as 1956, the CSAGI (English translation: Special Committee on the Geophysical Year) put forth a Proposal for Data Interchange in the IGY Rocket and Satellite Programs. "Interchange" was a more accurate term than "exchange," given the fact that there was no expectation of one-to-one exchanges of like data for like data from country to country. Rather, each country would contribute its own heterogeneous mix of information, at times concerning its own hardware, at times in observing other nation's instruments.

Within the proposal, CSAGI members offered important precedents for data exchange, simply stating that the following would be published in the forthcoming CSAGI "Rocket and Satellite Manual" and that supplements would be made available as new information arrived. Its precedents of data exchange included the following:[331]

Sounding Rocketry Data: This included the types of rockets launched, descriptions, altitude ranges, schedules of firings, objectives for on board instrumentation, and accuracy of experiment.

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[331] "Draft of preliminary proposal for data interchange in the IGY Rocket and Satellite Programs" Lloyd V. Berkner, Reporter for Rockets and Satellites Dec 19, 1956.. File USNC Member File, Newell H. E., Technical Panel on Earth Satellites Program Correspondence, NAS.

Experimental Data: The draft requested that, "Within a few weeks after each rocket firing…a report will be submitted to the World Centers for international distribution as appropriate." These would include descriptions of the firings, objectives, flight information, rocket information, pyrotechnics and weights, range instrumentation facilities including radio frequencies, and radar and beacon telemetering. Final conclusions of IGY rocket experiments were to be published in the open literature. These included measurements of atmospheric structure, solar radiation, ionospheric ionization, earth's magnetism, aurorae, cosmic rays, etc. They were to be published "as soon as possible" "in journals of general availability and of recognized standing" with reprints deposited in World Data Centers.

Data for Radio and Optical Satellite Tracking Stations: Information "needed by the nations participating in the IGY in connection with the establishment and operation of ground stations," included the visibility of satellites, observational methods, operational information for radio tracking systems, on-board transmitter characteristics, methods of data encoding and storage, feasibility of reception of telemetered signals by general observers, location of stations, and "recommendations by satellite-launching nations as to desirable sites for establishment of such stations by other countries."

Launching Information: CSAGI requested launching information that its representatives deemed "necessary if IGY participants throughout the world are to observe successfully the IGY satellites." This information included launch site, orbit inclination, approximate period of launchings, radio, telegraph, and press announcements within one hour after launch as to success and repeated as necessary.

Short-Range Prediction Data: This included satellite altitude, latitude of orbital subpoint, longitude of orbit subpoint, values for each given in for time intervals of one minute with a true accuracy of one second (using kilometers and to 0.1 degrees), additionally, "all current values of orbital elements will be made available regularly upon request and in accordance with individual arrangements."

Precision Observations of Satellite Orbits: This orbit data derived from tracking observations should be provided with two-directional angles, time, and place of observation must be published within five months in a standard periodical of astronomy having wide international circulation. Ephemerides were to be expressed in 10 meters in space and 10^-3 seconds in time. Raw data—be it film records, optical observations, or radio observations were not deemed suitable for exchange, but would "be made available for consultation at the World Data Centers."

Observational Data on Satellite-Borne Experiments: Within eight months of launch, data from satellite experiments were to be submitted to World Data Centers in reduced, corrected, and calibrated form. In the event that solar batteries or other improved power sources permitted the operation of experiments for longer than a two or three week period, bi-monthly increments of fully reduced data were requested for the World Data Centers with no more than an eight month delay."[332]

The sources and time at hand do not allow for an analysis of what elements of this proposal may have been disputed, creatively distorted, or amended. However this does provide a glimpse at the aims of the IGY leadership. Tucked within these data

[332] "Draft of preliminary proposal for data interchange in the IGY Rocket and Satellite Programs" Lloyd V. Berkner, Reporter for Rockets and Satellites. File USNC Member File, Newell H. E. Technical Panel on Earth Satellites Program Correspondence, NAS.

interchange agreements were both promises to international partners and requests of them, setting norms for standardizing data, its circulation, but also setting a carefully-regulated example of national transparency with dual use technologies. As with the UARRP's decision to treat scientific data about rockets as unclassified information, these data, too were necessary for divining natural processes, but they also provided useful glimpses into the engineering of dual use hardware from missiles, to satellite tracking, to radio direction-finding, and radar's function within the natural (and manmade) electromagnetic environment. If followed, even in part, these data interchanges would achieve a number of things: it would advance scientific understanding of the earth's geophysical properties, it would expose scientific researchers and their policymakers to precedents of data exchange, it would lessen information asymmetries among contributing nations, and provide a useful reference for the capabilities, interests, and perhaps even aims of partner nations' scientific programs. The Interchange Proposal functioned as an invitation to all these things.

In April 1958, Chairman of the IGY Joseph Kaplan, was called to testify before Congress on the details of NASA's formation. When asked his outlook on the exchange of scientific information with international partners, he communicated great enthusiasm. Having served as the geophysics chairman on the Science Advisory Board and having worked many years with the Air Force, Kaplan reported that the UARRP had "released all the [UARRP] information." Indeed, Kaplan was certain that the US was the only nation "that had used rockets for upper atmospheric soundings and published all the information freely." The result? Leading theoretical physicists in England along with "dozens of men, men from our allies and men on the other side of the Iron Curtain," analyzed the data. Because the UK researchers tended to be stronger in theory than their US counterparts, Kaplan and his colleagues only stood to benefit. The program had been improved and sounding rocket researchers in the Antarctic and Fort Churchill, Canada were progressing "marvelously."[333]

James van Allen (who had moved from APL to Iowa State University) used the success of the IGY to remind policymakers of the practical benefits of maintaining independent military and civilian programs. Referring to the Minitrack stations monitoring Vanguard, Explorer, and Sputnik satellite orbits he observed:

> …at the present time we have IGY satellite observing stations distributed over the world in at least twenty countries. Both practically and diplomatically, this is a very fine undertaking, but it is not at all clear how such arrangements can be managed if space is a military undertaking. I think it is rather difficult to imagine, let us say, the United States Air Force and the Soviet Air Force collaborating on any undertaking…[334]

Thus the political palatability of IGY collaboration—as a temporary and near-global agglomeration of state resources for the pursuit of geophysical science—was a critical part of the initial conceptualization of NASA and its mandate, opening geographies and pocketbooks.[335]

In April 1958, Eisenhower officially proposed his general notion of a civilian space agency to Congress, centered not within the Atomic Energy Commission, but

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[333]Aeronautics and Space Exploration Hearings of the Select Committee on Astronautics and Space Exploration 95th Congress, HR 11881, April 15 – May 12, 1958 (Government Printing Office, 1958). April testimony, 1132. Hereafter HR 11881.
[334] Van Allen was at *Hearings before the Select Committee on Astronautics and Space Exploration, 85th* Congress HR 11881 (April and May 1958) Cited in Frutkin, 29, 79.
[335] The IGY was not entirely "non-military," in the sense that plenty of tactical value could be derived from IGY research. The value of IGY research to the US (and other nations') militaries is evident in the fact that the armed services often provided logistical and personnel support.

instead adding manpower and greater bureaucratic potency to the NACA. This ostensible redundancy between military and civil programs demanded a painful compromise for the fiscally conservative president. Eisenhower's own experience at this juncture was shaped by two overlapping tensions: one with Congress over spending and the other with the Defense Department centered on wasteful duplication among the services, unnecessary interservice rivalry, and too much power being centered in the DOD.[336]

Diverging Weather Satellite Communities: IGY, ARPA, and the National Space Agency

> [The new space agency] would have an important function in making it possible for us to get the basic data, viewing the atmosphere from outer space.[337]

US Weather Bureau researchers remained eager to make use of meteorological satellite data for fundamental research explaining atmospheric phenomena as well as applications such as weather prediction and possible weather modification. When he was called to testify before the House of Representatives in the spring of 1958, USWB Chief Reichelderfer communicated his Bureau's stand on the matter: the USWB did not want to fund or design weather satellites *per se*. Reichelderfer used existing USWB practice to illustrate: "...it would be absurd for the USWB to have ships in the ocean to gather to gather weather reports [data]. Instead, we gather the reports from ships that are there for another purpose."[338] Reichelderfer's reference to the Voluntary Observing System—with roots extending to the 1850s—provides important insight into the USWB's removed stake in future of US weather satellites. Rarely had the USWB designed its own

[336] Iwan Morgan, *Eisenhower Versus the Spenders* (London: Pinter Publishers, 1990).
[337] HR 11881, 916.
[338] Ibid, 916.

instruments, instead, it focused on acquiring data and making the most of it—standardizing practice, expanding its pool.

Except in rare circumstances such as wartime interruptions, the fungibility of weather data remained a given, particularly among governmental organizations. Weather data was a commodity shared among the US armed services and the USWB, among commercial ships at sea, and routinely contributed to international circulation (the WMO in particular) where it could reach potential and real adversaries. Perhaps more important, USWB predictions derived from such weather data were viewed as a distinctly *public* commodity: at once available to, and affecting, the US as a whole. Earlier in his testimony, Reichelderfer had elaborated on the extent of communities benefiting from USWB predictions. His testimony included US regions, industrial sectors, agricultural pursuits, air and ground transport. The aging meteorologist recalled that roughly a decade prior the Bureau had undertaken a study to determine the value of forecasts and storm warnings to the public and national economy. "However," Reichelderfer confessed, "the figures that were presented to us by business and agricultural interests were so high that we never have been quite willing to come out with the values for fear that someone might think we were exaggerating. They were well in excess of a billion dollars a year."[339] Many of these users of USWB predictions— airports, industries, armed services and the like—reciprocated with local weather observations.

When the WB Chief demurred on the possibility of the WB launching its own satellites, he may have done so presuming that the WB and the space-agency-to-be would offer reciprocal services to one another. Reichelderfer opted not to mention the long

[339] Ibid, 910.

history of collaboration between the US armed services and the USWB, sharing data and storm observations. Like plans for Vanguards and Explorers, satellites designed and operated for the IGY, Reichelderfer postulated that future satellites would be launched "for general purposes," serving a variety of research and operational communities. As in the past, "what we want again" he said, "is to get a ride to get the weather reports we need without becoming a space agency ourselves."[340] The WB anticipated the right to design and/or influence the design of satellite payloads but *a priori* abdicated any rights to launch its own satellites. Speaking of what would become NASA, the WB Chief predicted, "The new Agency will have, I understand, the responsibility for the satellites where we would get our source of information."[341] Reichelderfer's expectations mated with executive policy.

Indeed, it seemed as though the new space agency certainly *ought* to have responsibility for designing and launching US weather satellites. Eisenhower wrote to the Secretary of Defense and the Chairman of NACA on 2 April 1958, directing that "the new Agency will be given responsibility for *all* programs except those peculiar to or primarily associated with military weapons systems or military operations."[342] The Eisenhower administration, then facing its second recession in five years and roughly nineteen months from Eisenhower's famed farewell address warning against "unwarranted influence" of the military-industrial complex sought to avoid unnecessary duplication of effort between ARPA and the new Agency, but also to draw clear lines of

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[340] HR 11881, 916.
[341] Ibid.
[342] Emphasis original. John Logsdon (ed) *Exploring the Unknown: Selected Documents in the History of the US Civil Space Program Volume I Organizing for Exploration* , 644 Memo for the President from Director of the BOB, May 13, 1958.

authority and jurisdiction. For a time, the Administration depended upon the (complicated) notions of "science" or programs with "no immediate relationship to established defense needs" to distinguish between ARPA and NASA mandates.

By July 29, the legislative and executive branches had settled upon the National Aeronautics and Space Act in which Congress declared, "that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind."[343] NASA's Administrator of International Affairs (whose background had been in the IGY), Arnold Frutkin would later describe this as "a bill to create a new civilian agency for the purpose of achieving national leadership in space, in a framework of peaceful purposes and international cooperation." Building upon the old NACA, such activities would be directed by a civilian agency exercising control over aeronautical and space activities sponsored by the United States," with the important exception of, "activities particular to or primarily associated with the development of weapons systems, military operations, or the defense of the United States (including research and development)" which would fall under ARPA and the armed services.

US space policy would not be so much compartmentalized as it would be coordinated between a NASA and ARPA, two sides of the same coin. For some, such as Eisenhower, James Killian, and others in-the-know on Air Force reconnaissance satellite program, diplomatic posturing inherent to the "peaceful purposes" mandate of NASA provided a palatable public façade to balance (if not function as an outright front) for ARPA's tactical reconnaissance, covert weather reconnaissance, communications satellite systems, and navigation satellites on the drawing board. But for Harry Wexler of

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[343] http://history.nasa.gov/spaceact.html

the Weather Bureau, William Stroud of the Signal Corps, and countless other IGY researchers, the institutionalization of IGY principles in NASA promised sustained funding for knowledge-driven research, a non-military institution for international collaboration, and freedom from the necessity of justifying all space R&D by its immediate contributions to the armed services.

Whereas meteorological satellites were perhaps the most obvious civilian space [read NASA] application, the Weather Bureau, the most logical *user* of civilian meteorological satellite data, denied having any interest in *operating* such a joint weather satellite program. ARPA plans for meteorological satellite systems continued apace. Whereas Bill Stroud and his team at the Army Signal Corps Research Lab had already developed meteorological satellite instruments for the Vanguard satellite program, they had also begun development work for the Army's follow-on operational satellite system, eventually named TIROS. Expecting NASA to bear the expense of satellite development and launch, the WB preferred to consolidate its extremely meager resources in data handling, weather prediction, and basic research.

At this point, all that was settled was that NASA would be a non-military institution, that it would be a center of space science research, and that it would subsume the old NACA's facilities and manpower. Significantly, the Space Act included imprecise language indicating that the NASA would *only* perform basic research. The armed services were left to presume that meteorological satellites were instruments for tactical support and therefore would remain in the DOD. Lyndon Johnson later observed that the Space Act "whizzed through the Pentagon on a scooter" before Easter holiday.[344]

[344] Killian, 135.

What remained uncertain? The House Representatives in particular wanted NASA to have enough bureaucratic clout to stand up to DOS and armed services, this would have to be settled in the drafting and re-drafting of the Space Act between April and July. The next chapter will address the ambiguities of NASA and how between April and October, NACA officials set policy precedents that were counter to the wishes of the Weather Bureau, White House, and Congress.

CHAPTER 5
'The Weather Bureau is About to Enter the Space Age'
Coordination for Meteorological Satellite R&D

> …the longer range research and early development programs on missiles, satellites, and the exploration of space should be directed by an agency with funds to insure the best utilization of research and early development facilities in universities, in research organizations, in industry, and in the Department of Defense.
>
> Fred Whipple, Smithsonian Astrophysical Observatory Director[345]

When the White House and Congress wrote legislation for a National Aeronautics and Space Administration, they were in many regards trying to leap onto a fast-moving ill-defined object. Of Congress, the White House, the public, and even representatives of the Defense Department, very few individuals voiced a desire for a national space program centered entirely under the Defense Department. In the crisis atmosphere following Sputnik I, the creation of *an* organization under the DOD was logical, but early on notions of a non-military counterpart were under serious consideration. With this in mind, ARPA, giving it 12 months to get the entire US space program off the ground (as it were) and implicitly, time for a national civilian space program to be legislated.[346]

However space science expertise was embedded almost entirely in the military and its contractors in industry and academia. For decades, the Army, Navy, and Air Force had been investing resources into manpower and technologies for operation in the upper atmosphere and space. When in house capabilities were insufficient, they partnered with

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345 Satellite and Missile Programs Hearings Part II, 2133.

346 Public Law 85-326 February 12, 1958; the law does not specify space, but simply designates authority to pursue "projects essential to the Defense Department's responsibilities in the field of basic and applied research and development which pertain to weapons systems and military requirements…,"13.

industries, universities, or the NACA. Through the UARRP-RSRP, researchers in armed service R&D organizations had voluntarily coordinated R&D with universities, industry, international partners, and kept institutions such as the Weather Bureau appraised of their activities. Representatives of the Weather Bureau and National Academies of Science also viewed themselves as possible assets and advisors to a national space agency (be it military or civilian), but at the same time hoped to shape space policy to better meet public needs.

As a national space establishment, NASA was intended to coordinate all these interests with the priorities of the White House and Congress. However NASA was not formally defined until the Space Act was approved in late July 1958 and NASA did not become an actual institution until 1 October 1958. Between April and October, NACA officials attempted to represent NASA interest, but did so compromising civil space policy in the eyes of the USWB, Bureau of Budget, and White House.

Thus, Weather satellites were situated at a complex intersection in bureaucracy: NACA/NASA officials viewed themselves as having been tasked with R&D for space systems, but not day-to-day operation of operating systems (though they could, in their opinion, operate *experimental* systems). The USWB did not have the mandate to perform space R&D nor to operate meteorological satellites. At the same time, millions of dollars had already been allocated to Army and Air Force meteorological satellite projects underway.

For a time, NACA officials forfeited any interest in operating the national weather satellite system on the presumption that the armed services would share data with the USWB. USWB officials, having no satellite system and having been denied mandate over ARPA meteorological satellite data, perceived this as yet another encroachment of the military into their jurisdiction.

Weather satellite systems were so big, expensive, complicated and so politicized that only *after* the USWB had secured its own system could they begin setting their own policies for international circulation of US weather satellite data. Here again, Francis Reichelderfer invoked his perception of the Weather Bureau's authority over US basic atmospheric research.

A Promising Start?

When Congress edited Eisenhower's 2 April 1958 draft of the Space Act, they amended it to give NASA more power within the federal bureaucracy. In particular, analyst Eilene Galloway prompted Senator Symington to make it an administration and not an agency. In their perspective, the national space establishment lacked sufficient bureaucratic clout to carry out its mission. To a few key individuals in Congress, including Senators Russell, Symington, and Johnson, NASA was intended to wield a strong coordinating power. While the DOD figured prominently in this concern, in order to bring the US into a position of international leadership in space, NASA needed clout *vis a vis* the State Department, Commerce Department, PSAC, the Atomic Energy Commission, US Information Agency, the Smithsonian Astrophysical Observatory, Federal Aviation Administration, National Academies of Sciences, Department of Treasury, ARPA, and all the armed services were just a few of the bodies with which NASA needed to coordinate policy.[347] Galloway years later recalled, "creating NASA as

[347] "I knew that NASA could not have a program of international cooperation if everything had to come to the Senate" p 34 Logsdon, *Legislative Origins*, 34. http://www.nasa.gov/50th/50th_magazine/gallowayEsaay.html

an administration was the best solution to the problem of coordinating under centralized guidance the programs of the new space institution and other executive agencies already engaged in space-related activities."[348] However NASA administrators would not be eager to take on this coordinating power.

Between 13 and 15 May 1958, Congress' Special Committee on Space and Astronautics held a session regarding a bill to provide support for research into problems of flight within and without the earth's atmosphere.[349] When discussing whether or not the new space establishment would perform research and/or the operation of satellite systems, NACA's Hugh Dryden offered meteorological satellites as a specific example, saying that the NASA would indeed operate such vehicles for the Weather Bureau so the US, "would not have 8 or 10 Government agencies independently putting up satellites."[350] USWB officials were quite pleased with this division of labor and took this as an opportunity to underscore to Congress their enthusiasm for the utility of weather satellites. Wexler spoke at length about the Suomi IGY radiation budget experiment that would be used to measure the Earth's reflected and outgoing radiation to space. Looking to an ambitious future, Wexler stated that the IGY was "merely the beginning." "We think that by the development of improved instruments, we can measure other properties of the atmosphere, such as temperature, winds, total amount of water in the atmospheric

[348] Ibid.
[349] National Aeronautics and Space Act Hearings Before the Special Committee on Space and Astronautics US Senate 85th Congress, Session on S. 3609, A Bill to Provide for Resarch into Problems of Flight Within and Outside the Earth's Atmosphere, and for other Purposes. May 13-15, 1958, 263. Hereafter S. 3609.
[350] Ibid.

columns [meaning at different altitudes]…and other important properties that cannot be undertaken during the present *short* International Geophysical Year."[351]

For these researchers, NASA would function as a continuation of the IGY—as a source of sustainable funds for scientific research, as an organization to coordinate national scientific and technological communities, and as a US representative in international collaboration. Senator Lyndon Johnson attached great significance to NASA's mandate to collaborate with international partners. When questioning NACA's Hugh Dryden about the executive branch's re-drafting of the Space Act, Johnson asked Dryden why international collaboration was not included in the White House's original bill. He did this either to assure that NASA's mandate for international collaboration would remain in the Act, and/or he did this as a means of political posturing to underscore his interest in NASA's role as a leader of international space activities.[352] To the State Department and White House, it was unnecessary for the Space Act to explicitly lay out NASA's right to collaborate with international partners. Johnson asked Dryden to clarify why it might be in NASA's best interest to keep international collaboration explicit in the Act. Dryden responded that doing so would be: "in order to emphasize the desire in setting up the new Agency to work for peaceful purposes and to join with others in the world in this direction, it is better to have something specific in the bill."[353] Guyford Stever, Associate Dean of Engineering at the Massachusetts Institute of Technology and Chair of the NACA Special Committee on Space Technology

[351] Emphasis added, S. 3609, 370.
[352] Ibid, 254.
[353] Ibid.

summarized the policy in eloquent candor: the first objective was, "to prove to the world that we are interested in and will lead in the nonmilitary uses of space"[354]

Stever's and Dryden's interpretation of the draft Space Act sets up a frustrating paradox in the evolution of weather satellite policy. In spite of Dryden's 13 May testimony stating that NASA would operate meteorological satellites for the USWB, that very same week the Bureau of Budget contacted Eisenhower indicating that NACA had signed away a number of projects intended for NASA to the DOD's Advanced Research Projects Agency.[355] While weather satellites are not mentioned specifically in the memo, NASA and USWB documents do indicate that NACA officials did alter course from the May 13 testimony. Either NACA officials expected the US government to pay for the development of two independent satellite systems (one designed entirely by NASA for the USWB and one by ARPA for the armed services) *or* NASA had signed away the national military-civilian weather satellite system by endorsing ARPA's plans for its own post-IGY satellites.

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[354] Ibid, 273.

[355] *Exploring the Unknown Vol*. I, 644. 15 May, the Director of the Bureau of Budget was writing Eisenhower, informing him that the NACA team had reached an agreement in which ARPA contrary to White House wishes. NACA, feeling obligated to accept an agreement "on the best terms acceptable to Defense" had signed away human spaceflight and the million pound thrust rocket engine. In April 2 letters coinciding with his submission of the Space Act, Eisenhower had written to the Defense Secretary and NACA Chairman that, "the new Agency will be given responsibility for *all* programs except those peculiar to or primarily associated with military weapons systems or military operations." Instead, months before NASA had even come into being, the Chairman of NACA had signed away all interest in space programs. The Bureau of Budget and White House viewed these projects "lacking an immediate military application," therefore belonging in NASA.

Obtuse language in the NASA Space Act—language that in part facilitated its "whizzing through the Pentagon" before Easter recess—led eventually to misunderstandings centered around two unclear notions. One was defining precisely what the technologies were to remain in the military. Weapons systems were easily identified, but to what degree did weather satellites constitute systems "peculiar to or primarily associated with military weapons systems or military operations"? Second was the question of whether or not NASA was supposed to "operate" systems in space or whether, like NACA, they were primarily an R&D organization developing technologies for (other) users.[356] From NASA's Glennan Administration until the Space Shuttle, NASA has interpreted this conservatively, developing systems and providing technical support when needed, but not operating *operational* systems.[357] Perhaps interested in maximizing the use of resources at hand (i.e. already in development by the armed services), the NACA-NASA transitional officials simply worked in support of ARPA. Given the fact that meteorological satellites certainly *were* of direct military application and that the DOD had such a significant lead in development, it was reasonable to NACA officials to continue supporting ARPA in meteorological satellite R&D. If NACA was planning to develop meteorological satellites for the USWB down the line, they clearly gave no such indication to the USWB.

[356] In Eilene Galloway's words, "NASA could have been research and development *and operations*, but there was a mind-set that came over from NACA…we could have amended [the legislation] if we just thought [it] was ambiguous." Emphasis added. Logsdon, 33.
[357] A special amendment was made to the space act so that NASA could design and operate the Shuttle.

ARPA's Meteorological Satellite Plans (Minus the USWB)

The summer of 1958 brought disappointments and frustration for the Weather Bureau. USWB officials wondered the degree to which satellite studies and atmospheric research were being conducted by the DOD and concealed by classification restrictions. In spite of having attended recent ARPA meetings, Wexler remained uninformed, but for a "vague rumor" that research was being performed at the Air Force Cambridge Research Center-Geophysics Research Division and also the Signal Corps Research Lab.[358] These rumors were accurate.

By 6 June, Reichelderfer, having apparently received no word from NACA-NASA on meteorological satellite coordination, completely changed tack, proposing to the Commerce Department that they fund "substantial budget in satellite meteorology." With this money, he intended for the USWB to begin its own weather satellite program, circumventing ARPA, supporting Suomi's group at the University of Wisconsin, developing new meteorological satellite instruments, and instituting a USWB satellite data analysis unit under Sig Fritz, (who would indeed run the USWB Meteorological Satellite Section when NASA began funding it later in the year). However, the Bureau of Budget refused to fund satellites under the USWB. Wexler was uncertain if the program would even go to NASA upon its formation, but was certain the delay would "set us back quite a bit in our scientific space program."[359] The longer it took for the new space agency to officially come together, complete with the bureaucratic power intended by Congress, the more time ARPA spent at the helm of US meteorological satellite development. Given the fact that NASA had not yet formally formed, nor had an

[358] Wexler to Kellogg, June 6, 1958, General Correspondence 1958, Wexler Papers.
[359] Ibid.

administrator been selected, NACA representatives (described frequently as captives of the military industrial complex) represented NASA interests, essentially rubber-stamping ARPA plans for space programs.[360]

For their part, the armed services and their labs took a keen interest in the success of weather instruments on Vanguard and Explorer satellites and were making plans for follow-on projects for weather reconnaissance. The Army Signal Corps would run systems integration for the RCA photocell experiment along with command and data acquisition for the Vanguard II weather instruments. Von Braun's team at Army Ballistic Missile Agency were retrofitting the Suomi heat budget experiment to mate with the Explorer VI satellite bus. At this time, the NRL remained "very much interested in weather reconnaissance" and even considered developing a branch of the lab in that field.[361] Meantime, the Air Force Cambridge Research Center/Geophysics Research Division began exploring methods for processing, analyzing, and applying satellite data to tactical use. They did this in-house but also contracted with Florida State University, the Imperial College of Science and Technology in London, England, and the Blue Hill Observatory at Harvard University. Beginning in the spring of 1958, results from these earlier studies provided quantitative analysis of camera resolution required for assorted types of cloud information and radio bandwidth for telemetering data back to ground stations.

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[360] Keith Glennan was sworn in as NASA administrator 19 August 1958. NACA officially became NASA on 1 October.
[361] Rocket Sonde Branch Interest in Space Research Program Activities. NRL Lists weather satellites as number five of seven tasks. Folder Ad Hoc Committee on Rocket, Satellite, and Space Research, 1958, Box 2, Folder 3, Smithsonian.

On the 24 June 1958, NACA hosted a "scientific satellite payloads" meeting concerning the "future status of meteorological payloads." Present were a bevy of representatives from armed services who would be dependent on these systems for operations as well as research. The Air Force Cambridge Research Lab, Jet Propulsion Lab, Ballistics Missile Division, the Naval Research Laboratory, Office of Naval Research, Army Ballistic Missile Agency, Naval Weather Research Facility, Army Signal Corps Research Lab, Office of the Chief Signal Officer (Navy), Office of Chief of R&D (Army), Office of the Assistant of the Secretary of Defense, Wright Air Development Center (USAF) were present; NACA, the USWB, and the University of Wisconsin were the only non-military organizations in attendance. No indication was given whether the National Academies of Sciences was invited or consulted in any capacity, which would have been logical given their management of the IGY weather satellites and their planned influence of the Space Science Board as an advisor to NASA.[362]

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[362] See Robert Smith, Naugle, and Newell for details on NASA's relationship with the NAS and Space Science Board. The Glennan diary, *The Birth of NASA,* offers a provocative encapsulation of the NASA-NAS relationship: "At noon, the members of the space science panel of the President's Scientific Advisory Committee came in for lunch. They had sent us a long memorandum of complaint about the manner in which we were dealing with the scientific community, so called. Homer Newell did a fine job of answering, very patiently, each of their complaints. Lloyd Berkner was his usual dominant self, but we managed to deflate him a little bit during the course of the discussion. Actually, the scientific community, as such, is a bunch of spoiled individuals - the higher they rise in the hierarchy the more spoiled they become. In this instance, at least two of the men present spent most of the time arguing over projects in which they were involved. Conflict of interest? Not at all - they are scientists! In spite of these statements, these are good people and their voices must be heard. We are doing our best to accommodate their interests and to handle our program so that a maximum number of them are involved. On the other hand, the responsibility for the make-up of the program and the expenditure of the money cannot be delegated to any group outside of the

Resolving that a "basic scientific understanding about our world" was necessary, the NACA meeting participants discussed continuities between the IGY Suomi and Stroud experiments and follow-on experiments being funded by the armed services. Although the panel was stacked with researchers supported by DOD funds, they held similar priorities to the Weather Bureau, but in a different order: Stroud's television cloud cover experiments came first and Suomi's earth radiation balance second. Third, they desired Stroud's photocell experiment operating in the visual IR range and fourth an experimental TV system sensitive to IR.[363]

Given the fact that the Army TV-IR satellite (still not formally named TIROS) was based on well-developed plans for a reconnaissance satellite as well as simpler in design than the Air Force's plans, it was deemed the closest to operational.[364] Meeting participants discussed the challenges of inserting this new satellite system into pre-existing networks of IGY satellite system hardware as well as institutional networks already trading weather data. The space science community (in particular, NASA's Vanguard team and Stroud's Signal Corps team) would oversee modification of the satellite to accommodate a Minitrack instrument. This meant bandwidth would permit a maximum resolution of 1200 x 1200 mile picture. The armed services, which for years had shared meteorological observations with the US Weather Bureau and allies abroad,

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government." May 5, 1960, *The Birth of NASA: The Diary of T Keith Gennan* (Washington, D.C.: NASA SP-4105).

[363] Attendees of June 20th meeting at NACA Headquarters re scientific satellite payloads, Project TIROS Record Number 6467, NHRC.

[364] In April of 1958 ARPA cancelled the ABMA-RCA reconnaissance satellite (citing it as an unnecessary duplication with the Air Force's SAMOS satellite) and had it transferred to the Army Signal Corps Lab to be developed as a meteorological satellite system.

made the astute observation that meteorological observations could be "telemetered directly to foreign stations while overhead with obvious propaganda advantages."[365]

At the June 1958 NACA meeting, the Air Force presented the most elaborate proposal for an integrated meteorological system, based on the 117L (117L was the predecessor to the Discoverer scientific satellite, SAMOS reconnaissance satellite, and MIDAS Missile Detection Alarm System). Weighing three thousand pounds, NACA's minutes reported that it "would measure everything possible in the way of meteorological information" and would cost $88.8 M.[366] This system, the 117-W, would by far exceed the receiving capabilities of the Minitrack stations, necessitating part time operation of satellite remote sensing equipment. While the Army volunteered the observation that sharing data would benefit the US's public image, meeting notes do not indicate to what degree the Air Force intended to share their observations with the USWB or international partners.

The armed services, eager for immediate operational coverage of cloud cover patterns and data regarding the earth's heat budget determined that the proper course of action would be to launch the Army's lighter simpler experiments as soon as practicable while continuing R&D on the Air Force's more complex system. Thus, they favored foremost the RCA TV (capable of 3.5 mile resolution), more versions of Suomi's Earth Radiation Budget, the Stroud experiment with photocells in the visible IR range, and a TV system sensitive to various IR wavelengths. These experiments would help better

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[365] Attendees of June 20th meeting at NACA Headquarters re scientific satellite payloads, Project TIROS Record Number 6467, NHRC.
[366] Types of observations included cloud cover, cloud definition, cloud layers, and thickness, moisture content, ozone content, wind direction and velocity, albedo, spectra of incoming radiation, reflection and absorption of this radiation by earth and various cloud and atmospheric layers, overall heat balance, and lightning location.

define the specifications for the Air Force's 117-W equipment as well as deliver "useful information soon!"[367]

USWB Response to ARPA's Control of Meteorological Satellites

Harry Wexler used his participation in the National Academy of Sciences to try to influence what meteorological instruments would be used in IGY follow-on satellites. Because expertise necessary to plan and operate IGY satellites had amassed in NAS IGY committees (such as the Technical Panel on Earth Satellites and the Meteorological Committee on which Riechelderfer served), both Congress and the White House desired that the NAS would continue to influence national space policy in the years following the IGY. Thus, in June of 1958 Lloyd Berkner, president of the International Council of Scientific Unions met with Hugh Odishaw, executive director of the new NAS Space Science Board, Herbert York, Chief Scientist at ARPA, and Alan Waterman of the NSF. The group determined that the NAS would continue to coordinate the work among ARPA, NASA, and NSF (an act later perceived by some NASA officials as overstepping NASA's mission to coordinate with the DOD through ARPA).[368] In July 1958, RAND meteorologist William Kellogg submitted to Wexler a proposal for an integrated military and civilian meteorological satellite to submit to the NAS Space Science Board. While Kellogg, too, prioritized the cloud coverage experiments first, he listed the Suomi experiment second. Third, the NAS desired solar UV and x-ray measurements and finally, a continuation of lightweight sounding rocket experiments.

[367] Emphasis original, Attendees of June 20th meeting at NACA Headquarters re scientific satellite payloads, Project TIROS Record Number 6467, NHRC.
[368] Naugle 29-33. See also Robert Smith.

To backtrack and summarize, because these are very important points: in April, the USWB Chief testified before Congress that he viewed it as outside the USWB's jurisdiction to pursue its own weather satellite program. Instead the USWB wanted data and, if possible, to provide input on the nature of instruments orbited on NASA satellites—all this "without becoming a space agency ourselves."[369] Convinced that the NACA was following and not coordinating ARPA interests, in the summer of 1958, Reichelderfer lobbied the Department of Commerce to pursue a weather satellite program of its own (the USWB was under the DOC), but was denied this by the Bureau of Budget presumably because the Space Act had not yet been passed and the BOB and Congress took it as a granted that NASA would build and operate meteorological satellites. Reicheldefer's willingness to pursue his own satellite system functions as an indication that the USWB was serious about pursuing weather satellites and willing to do so *with or without the backing of NASA*—but the Executive Branch blocked the effort, preferring that NASA coordinate the effort. At this time NACA-NASA officials entertained no intention of developing meteorological satellites, instead, NACA was providing support for future ARPA meteorological satellite R&D and NACA officials initially supported ARPA plans to give data handling responsibilities to the Air Force.[370]

Thus, the USWB began working with the National Academies of Sciences to determine parameters for a weather satellite system. Wexler was confident that between

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[369] H.R. 11881, 916.
[370] There is the remote possibility that when Dryden testified in May that NASA would operate USWB satellites, he was planning for NASA to develop a whole new system for the USWB, independent of the ARPA R&D satellites under consideration. If this was the case, he clearly made no effort to communicate as much to the USWB.

the NAS, the incoming NASA civil servants, and the explicit mandate for a civilian space agency, the USWB would at last be able to exercise some degree of authority over meteorological satellite planning and operations. Documents at hand do not give a clear indication to what degree the USWB was pushed from the ARPA-NACA committee and to what degree they defected by choice. After having attended several months of meetings with ARPA regarding the ARPA meteorological satellites, NACA's Edgar Cortright reported that the USWB and various universities "have been generally absent" after the first meeting.[371] Perhaps the USWB presumed that there would be an independent non-ARPA meteorological satellite program after the formation of NASA; perhaps ARPA had made it clear that USWB contributions were not needed and that other obligations took precedent over the USWB's operational interests. In spite of the USWB's nonparticipation in the NACA-ARPA meetings, NACA's Cortright insisted that he wanted the USWB to play a major role in the ARPA satellites. Tellingly, he also indicated NACA-NASA interest in "providing support for R&D on subsequent meteorological satellites and data handling and utilization."[372]

As a result two sets of plans were made, one meteorological satellite program came together under ARPA - NACA/NASA auspices, and a second between the Weather Bureau - NAS planners in hopes of directing NASA operations once NASA was officially on line on 1 October. During this time, representatives of what would become NASA engaged in deliberations concerning the formation of a joint data reduction/processing facility with ARPA's Roger Warner. Because the Army Signal

[371]Memo for the Associate Director, Advanced Systems: Meteorological Satellite Program, 28 August 1958. Project TIROS Record Number 6467 NHRC.
[372] Ibid.

Corps was the furthest along in satellite analysis studies, the NACA-DOD partners were clearly leaning toward launching their system in 1959, and using the AF Weather Research Facility as either an independent military facility or the dominant institution handling satellite data in a joint agreement. This situation puzzled and frustrated WB officials. There was no institution whose experience with atmospheric data processing exceeded the volume of data, or number of collaborators managed by the USWB. The USWB was also the US representative in the World Meteorological Organization, and as such a world leader in helping determine WMO methods and standards of data dissemination. Multiple times in 1958 representatives from both NASA and Air Force Weather Research Facility visited the facility and commented with favor on their operations and equipment. Yet in spite of all this, USWB officials were deeply concerned that the NASA would select the AF Weather Research Facility as the lead center for *all* meteorological satellite data reduction.

Nearly all of these events transpired before Keith Glennan had so much as been asked to serve as the first NASA Administrator (on August 7) or even laid eyes on the Space Act.[373] Glennan was sworn in on 19 August, which coincides with a definite increase in activity between NASA and the USWB. On 29 August 1958, Roger Warner ARPA Chair for Meteorological Satellites brought up the topic of data reduction to USWB Harry Wexler, pointing out that he recognized control over data reduction was a "thorny problem." Wexler asserted his and the USWB authority, pointing out that as opposed to the satellite systems proper, data, "was one area where I felt the Weather Bureau would want to come in very strongly." Warner cautioned Wexler that he would

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[373] Glennan *Birth of NASA*, 7 Aug 1958.

be disappointed with the ARPA-NACA decision on data reduction and informed him that a NACA representative would break the disappointing news to Wexler formally. When Warner informed Wexler that ARPA would remain willing to "cooperate with" Wexler in NASA-ARPA Committee work, Wexler, with evident pleasure, invoked his authority as an NAS Committee Chair, retorting, "as Chairman of the Space Board Meteorological Committee I have incorporated the ARPA Met Committee plus others and would as occasion demands take advantage of his, Warner's, assistance *as consultant*.[374]"

That same day, USWB specialist in data analysis, Sig Fritz met with Edgar Cortright of NACA. Cortright, who became one of the USWB's more reliable supporters, shared with Fritz "interesting papers" prepared by Air Force Cambridge Research Center's William Widger, requesting money from ARPA to support (in Wexler's words) "basic meteorological research based on satellite vehicles."[375] Sources do not indicate the distribution limits or classification level of the papers. Furthermore, it is hard to determine the degree to which the Weather Bureau officials were riled that fundamental research—facts of nature—were being withheld behind classification restrictions or the principal that the Air Force was directing basic research *at all* and hypothetically at the "expense" of USWB research capacity.

With papers in hand and Fritz in tow, Wexler later tracked down USWB Chief Reichelderfer insisting that the WB should "go into it whole hog," and set up a hardware division as big as the instrument division in addition to reduction and analysis. Just a couple days later, 2 September 1958, ARPA briefed NACA-NASA representatives and

[374] Emphasis added. Satellite Diary, entry 8/29/58. Box 9, General Correspondence Folder, Wexler Papers.
[375] Wexler, Satellite Diary 8/29/58.

USWB researchers on their $5M plans for experimental satellites in 1959 and 1960. ARPA had reduced the run of satellites from nine to six, but Wexler did not receive a satisfactory explanation for the cut back. Of the $5M, $2.5M would be allocated to Army Ordnance Missile Command for an RCA contract on television instrumentation. Wexler also expressed distress that ARPA had asked NASA to perform data acquisition, processing, and a "reasonable" part of the analysis.

Wexler was greatly displeased. When the floor opened to discussion, he "reviewed the history of basic research in this country very briefly particularly the movement since the end of World War II for the military because of their greater financial capability to underwrite most of the basic meteorological research despite lack of Congressional mandate."[376] The USWB on the other hand had the federal mandate to perform basic meteorological research, but suffered perpetually insufficient funds. Two days later, Reichelderfer sent a priority memo to Wexler "Immediate Steps to Implement an Adequate Weather Bureau Program in Rocket and Satellite Meteorology." Reflecting on the role of the new Office of Rocket and Satellite Meteorology, Reichelderfer predicted that there would be many additional

> steps to be taken in cooperation with NASA, ARPA, and other interested agencies to make sure that the Weather Bureau and the national meteorological service have full participation in planning and developments for rocket and satellite meteorology, and that the Bureau has *full access to all the data*…[377]

Reichelderfer charged the office to be constantly alive to the fast-changing field and energetic in exploiting meteorological contacts. This and only this would "make sure that

[376] Wexler, Satellite Diary 9/2/58.
[377]Emphasis added. Immediate Steps to Implement an Adequate Weather Bureau Program in Rocket and Satellite Meteorology, 4 September 1958, Box 9, Folder General Correspondence, Wexler Papers.

the public interest in these meteorological developments is well represented and safeguarded." The Weather Bureau doubtless communicated their early September reorganization to NACA-NASA officials because on 10 September, Wexler wrote twenty-two colleagues, "The Weather Bureau is about to enter the Space Age." Following a visit to the Suitland data center, NACA-NASA representatives designated the USWB as their meteorological agent responsible for meteorological instrumentation, data reduction, and analysis for satellites after the IGY satellites series was finished.

Shortly thereafter, the House Select Committee on Astronautics and Space Exploration reported the clarifying statement, "Although weather and communications, manned platforms, and the like have obvious military uses, their primary purpose should be declared civilian." The report continued with the strikingly ominous reflection, "If we do not do this, we automatically commit the world of the future to the same stalemated life in armor which is lived by the world of today."[378] NASA policy was crystalizing at once in both the formal legislative sense and by precedents of evolving practice among the R&D communities.

NASA Opens For Business

NASA and ARPA began renegotiating terms for meteorological satellite R&D nearly as soon as Glennan was in office. Given the fact that NASA would not acquire the Minitrack tracking system, the Vanguard computation center, nor the 157 Vanguard personnel from the Naval Research Laboratory until February 1959, they would not be able to formally undertake actual satellite R&D for a several months. Thus, Glennan wrote ARPA Director Roy Johnson on 23 October of 1958. The earth satellite, he

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[378] Quoted in Hugh Dryden, "National Aeronautics and Space Administration, for presentation to Air Force Association, September 26, 1958. NHRC.

observed, “represents a new observational tool which promises to be of great value to the science and practice of meteorology.” Glennan then acknowledged the multiplicity of it’s values listing a number of benefits: protection of life and property in weather disasters, safeguarding transport, crop planning and protection, industrial planning of weather dependent products, prediction of heating and cooling loads, “eventual limited weather control,” and “good will in return for providing these services to less fortunate people.” Recognizing that the DOD also needed weather forecasting for aircraft and missile use over “silent” (meaning no weather data was available) landmasses, aerial refueling, jet stream determination, ship and plane routing, the planning of military campaigns, and military equipment design, Glennan suggested a new mutual effort to develop meteorological satellites.[379]

Glennan proposed that in support of ARPA’s weather satellite due to launch in the summer of 1959, NASA provide Minitrack support, data acquisition, and data processing (having already made the USWB their meteorological agent). Thereafter, NASA assured the DOD that it would pursue meteorological satellite development to meet the stated needs of *all* users and that ARPA participation was welcome in these programs. Significantly, Glennan pointed out that R&D on these satellites would be performed with the ultimate aim of transitioning an *operational* system to the USWB. While NASA would provide proper attention to securing satellite coverage of “silent” areas (such as oceans and countries such as China that refused to contribute to the WMO) and even modification of satellite instruments to meet military needs, Glennan maintained that dissemination of all weather satellite data would be under the USWB as was already the

[379]Glennan to Johnson, 23 October, 1958, Project TIROS Record Number 6467, NHRC.

case with non-satellite weather observations.[380] A Joint military-civilian Meteorological Satellite Unit was formed, this time housed under the USWB and welcoming representatives of the military services.

USWB-NAS Efforts to Expand Civilian Meteorological Constituency

With experimental (but not operational) meteorological satellites settled under NASA-USWB jurisdiction, the USWB could turn attention back to a concern pre-dating the IGY: achieving a more logical balance of resources and manpower between the Department of Defense and the USWB in the basic sciences. Wexler was open to the notion of a joint meteorological advisory committee to advise NASA and ARPA on satellite development, but cautioned against another instance of a joint committee "heavily overloaded with military representatives."[381] RAND's William Kellogg suggested that the USWB look to universities for participation, contrasting meteorology with ionospheric physics, he observed that the universities were not nearly as involved in meteorology.

The USWB had a variety of reasons to generate more university participation in their field, beyond stacking the joint satellite committee in their favor. Indeed, since 1956, the National Academies of Sciences Meteorological Committee had been speculating on how to attract more researchers to basic scientific meteorology producing more "basic meteorological knowledge."[382] This perceived shortage of qualified personnel was aggravated by Wexler and Reichelderfer's concern that too many

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[380] Ibid.
[381] For the Record: Conversation with Dr. W. W. Kellogg 22 October, 1958, General Correspondence Folder, Wexler Papers.
[382] See Chapter 3.

resources and too much latitude had been invested in the Air Force's growing Geophysics Research Division.

Presumably because NASA had selected the USWB to be their meteorological agent in data analysis, the USWB had redoubled efforts to better coordinate research efforts of the Air Force Geophysics Research Division and USWB meteorological satellite groups. It was as yet to no avail. Wexler explained three motivations for increased communication, if not a degree of consolidation, between the two. First, there was a shortage of personnel qualified to reduce and interpret satellite data and nephanalyses (images of cloud cover). Second, there were clear benefits to having the analysis group as near as possible to the National Meteorological Center serving the "main bulk of" the Weather Bureau, Air Force, and Navy analysis and prognostic needs.[383] Finally, improved coordination would avoid wasteful allocation on "unrealistically devised" contracting funds. Likely, Wexler was making a reference to his disapproval of the fact that the Air Force preferred to contract out a large share of its R&D operations with university and industry partners. At the bottom of his memo listing these concerns, Reichelderfer typed his encouragement to Wexler to keep him apprised of any "reluctance" on Warner's part regarding ARPA and USWB cooperation. In red ink it read: "WE MUST NOT let the military invade our field of responsibilities in this matter."[384] Reichelderfer phoned Roger Warner and ARPA director, Roy Johnson about the matter, planning a conference for the coming week.

[383] Conversation with Dr. W. Kellogg 22 October 1958, Box 9 File General Correspondence 1958, Wexler Papers.
[384] Ibid.

During this time, the USWB had been working in concert with the NAS and NSF to better coordinate the field of fundamental upper atmospheric research. Doing so would not only increase the amount of basic scientific research taking place under the auspices of the federal government, it would expand the USWB's constituency and expand the base of non-military stakeholders performing basic research on the upper atmosphere. To backtrack a bit, since 1956, Reichelderfer had been participating in NAS meetings to discuss the state of the scientific community. With the launch of Sputnik and subsequent state of crisis and re-assessment, like so many other scientific disciplines, the meteorologists engaged in a study of "manpower," research, and education. This report was shared with a group of meteorology department heads and after their endorsement, sent to the president of the NAS, the Director of the NSF, the Commerce Department (under which the USWB operated), factions of the DOD, and other relevant government bodies. The report concluded that "the total effort in basic atmospheric research was quite inadequate" and recommended first, that basic research in universities and kindred institutions be increased and second, that a National Institute for Atmospheric Research be established.[385]

The NAS committee called for the American Meteorological Society and for US universities to take more active parts in invigorating the discipline. The universities responded immediately with the formation of UCAR—the University Committee on Atmospheric Research in February 1958. UCAR's first report echoed the NAS's call for the establishment of a National Institute for Atmospheric Research. Their reasons

[385] University Committee on Atmospheric Research, "Preliminary Plans for a National Institute for Atmospheric Research" prepared for the NSF, February 1959. Hereafter UCAR Blue Book.

included the necessity of tackling fundamental atmospheric problems "on a scale commensurate with their *global nature and importance*," the fact that the extent of this research problem exceeded the facilities and technologies available to any one university, that these global problems necessitated the best talent from a variety of disciplines to be applied "in a coordinated fashion" on a scale beyond that of any single university, and finally, that it would preserve the "natural alliance" of research and education in a balanced fashion.[386] Parallel to the logic of the Weather Bureau, the Institute for Atmospheric Research planned to invest heavily in "ground" facilities but leave the rockets and satellites to agencies that already carried that mandate (NASA).

Instead, the Institute would have a spectroscopic lab, instrumented aircraft for radiation measurement and vertical profiles of ozone distribution, a "large-scale" computer for theoretical calculations. In addition to this, the Institute would design instrument payloads for launch on sounding rockets and satellites.[387] In July of 1958 the universities set up a nonprofit corporation and an agreement for cooperation, however the planning for (what became NCAR) stretched on into 1960.

The Vanguard Division Tools Up for TIROS

As demonstrated by the IGY Vanguard proposal—the NRL Vanguard Division embodied essentially all the skills to design, launch, and operate a satellite system, but not the meteorological specialists to interpret the observations. As of January 1959, NRL code directories indicate that the Vanguard Division "moved" from being a Division level organization within NRL, to being listed as an "Outside Activity," still on Navy property. Roughly 157 persons were included in this first main transfer of NRL manpower to

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[386] Emphasis added UCAR Blue Book, 7.
[387] UCAR Blue Book, 40

NASA, including phyicists, clerks, mathematicians, engineer aids, stenographers, electrical technichians, research engineers, and secretaries, from a wide range of operational units within the Vanguard Division including the Theory and Analysis Branch, Radio Tracking, XIB AM transmitter group, vehicles branch, and the program office.[388] The transfer to NASA came weeks before the launch of the world's first weather satellite, Vanguard II.

During the first week of February 1959, there were a series of "intense" meetings among the Vanguard Division, NASA Headquarters representatives, the USWB, the Army Signal Corps Research Lab, and ARPA.[389] Behind the scenes, NASA officials deliberated over their course of action regarding meteorological satellite R&D. John Hagen, still lead of the Vanguard group, was offered four choices regarding weather satellites: NASA might withdraw from the "foundering" ARPA meteorological enterprise to devote their entire effort to their own follow-on program that was "just picking up steam;" NASA might continue collaborating with ARPA, offering minimal time and money; NASA might renew request for responsibility for all phases of project after launch; or NASA might request responsibility for the entire project.

At this point, NASA had already begun work on its own "follow-on" R&D meteorological satellite system, distinct of and more advanced than the Signal Corps' experimental satellite.[390] In spite of this and the headaches of taking on an underfunded

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[388] List of Employees in Project Vanguard as of 9/22/58, RN 006625 NHRC.
[389] The Vanguard Team would not formally transfer to NASA from the NRL until 28 February 1959.
[390] ARPA claims that they named TIROS, but I see no evidence of that being the case in primary documents. Also, something of a misnomer given the fact that ARPA cut the IR out of TIROS well before NASA requested transfer. NASA began referring to TIROS I and II as such likely after they had started plans for follow-ons III and IV.

R&D project, Hagen selected the final option, requesting transfer of the entire project. Edgard Cortright was inclined to go with his choice since the Vanguardians were "the group which must do the work."[391] It is important to note that, similar to NASA's initial support of the ARPA meteorological satellite, this decision was made at such a relatively low managerial level, given the fact that TIROS satellites would soon carry great diplomatic significance. The final decision to actually *request* transfer of the experimental meteorological satellite from ARPA to NASA was left to those who would "do the work." In spite of the fact that the USWB wanted charge of the meteorological satellite data and in spite of the fact that Eisenhower's Bureau of Budget had ordained as much, it is evident that if the Vanguard Division had opted not to take on the partially-complete program, their managers would have supported them in the decision.

Sources indicate that design work on NASA's follow-on R&D meteorological satellite took place almost entirely independent of operational support to what became known as TIROS (see Table 6.1 for details). This means that had the Vanguard team demurred on acquiring the simpler former Army meteorological satellite (TIROS), the civil space program would not have launched a meteorological satellite launch until at least 1963-64. On one hand, the Vanguard team may have benefitted by investing 100% of their efforts in development and launch of their own in-house meteorological satellite (rather than taking on the hassles and shared credit of launching, operating, and using a satellite designed by others). On the other hand, transfer of the partially-complete TIROS system did abbreviate the lead-time to NASA's next successful satellite launch, important from an operations standpoint and a public relations standpoint.

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[391] Memo for Director, Spaceflight Development, Meteorological Satellites, Project TIROS Record Number 6467, NHRC.

In weighing whether or not to take on ARPA's TIROS meteorological satellite project, NASA management also debated whether or not to put in another request for the transfer of the Signal Corps' William Stroud and his team of approximately six.[392] Stroud had contacted NASA requesting transfer and NASA had sent a request to the Signal Corps that was denied based on the fact that Stroud was working on projects other than TIROS for the Signal Corps.

On 18 February 1959, the day after NASA's launch of Vanguard II IGY satellite, Administrator Glennan wrote to ARPA's Roy Johnson formally requesting the meteorological satellite project. The two had already met with Assistant Secretary of Defense Quarles about the matter and reached the conclusion of transfer, so the letter was a mere formality. There were at least three reasons that the transfer to NASA was logical: NASA had been active on the ARPA *ad hoc* committee since its inception (as NACA before that), they had a firm relationship with the Weather Bureau and had sponsored a Meteorological Satellite Section there that was progressing nicely. Last, the NASA administrator cited the Vanguard Division itself as justification for moving meteorological satellites from ARPA to the NASA. Due to this group's "considerable experience in satellite systems" and the fact that they had specifically organized a "strong group to conduct long range" meteorological satellite R&D, Glennan could assure the best possible management of the research program.[393]

Two days later ARPA's Roy Johnson responded amenably to the transfer, but cautioning that certain experimental results expected from TIROS were intended to

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[392] Sources do not indicate when NASA first requested transfer of the Army Signal Corps meteorological satellite group.
[393] Glennan to Johnson, 18 February 1959, Project TIROS Record Number 6467, NHRC.

establish the "base for a specific meteorological satellite development program" meeting "urgent military requirements."[394] Sources do not reveal precisely what the urgent military requirements were, however it is certain is that the Strategic Air Command took an interest in the quality of TIROS images *after* it had been launched (discussed later). Sources do not indicate how long Strategic Air Command had been following the progress of the meteorological satellite instruments, nor whether ARPA's TV or IR instruments were explicitly intended to function as proof of concept for Air Force weather reconnaissance (or even strategic reconnaissance) operations. Johnson's letter to Glennan offered a candid notification: that in spite of NASA's work on the centralized "national" operational satellite system, ARPA may initiate another program to focus military requirements. While it is unclear what SAC was doing or expecting in the spring of 1959, by 1960, SAC was biding its time, waiting to see how long it would take for the NASA-WB team to launch an operational—meaning 12-month a year—weather satellite system (to be discussed later in this chapter). Ultimately, Strategic Air Command would have two interests in operating its own meteorological satellite program. One interest was the retrieval of weather reconnaissance for SAC bombers conducting dangerous in-flight refueling. The second was that a weather satellite with lower resolution cameras could orbit "in front of" higher-resolution reconnaissance satellites performing cloud cover reconnaissance and determining whether or not the higher resolution satellite ought to use precious film imaging the earth, or whether cloud cover would obscure such a shot.

[394] Johnson to Glennan, 20 February 1959, Project TIROS Record Number 6467, NHRC.

The funding and intended application of Stroud's infrared experiment were likewise, complicated elements. As of the winter of 1959, ARPA had notified NASA that they would not have the money to pursue the IR instrument nor to include Werner Suomi's earth radiation budget experiment in their first meteorological satellite. Instead, they would focus their energies on two RCA television cameras with wide and narrow angle resolution. When in the first week of February the Vanguard Division considered transfer of the weather satellite program to NASA, part of their motivation had been the desire to reinstate Stroud's instrument and hopefully even transfer the Army Signal Corps team to NASA (Suomi's instrument was not mentioned specifically by NASA, though the USWB was deeply concerned about supporting his team).[395] That spring, NASA's Vanguard Division assembled a new joint meteorological satellite committee. As coordinator of military *and* civilian interest groups they sought representation more balanced in favor of universities and the USWB. Kellogg, who had crafted himself as a meteorological satellite expert for nearly a decade, was invited to sit in. Soon he would transfer from RAND to the National Center for Atmospheric Research.

In spite of having been transferred *on paper* to NASA, the meteorological satellite system remained in many ways the armed services' baby. Plans were for TIROS to be launched by the Army Ballistic Missile Division (BMD). The USWB would have the "meteorological data interpretation and use responsibility," but Navy Photo Interpretation Center would carry out the work of photo rectification. (This is the point at which the military would determine whether photos bore strategically compromising details for the

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[395] Memo For Director, 6 Feb 1959, Project TIROS Record Number 6467, NHRC.

US or other countries and in turn, whether or not it could be released.)[396] BMD and Lockheed would operate the data acquisition site in Hawaii. Army Signal Corps Laboratory was responsible for data acquisition from the satellite and monitoring the RCA payload effort. RCA Astro Electronic Products Division, was responsible for installation of the payload and ground equipment at data acquisition sites, answering to the Army Signal Corps.[397] NASA would manage the overall project, provide orbital computation and orbital control (using Vanguard hardware), and develop the infrared equipment on the payload (under William Stroud who would transfer with all but one man on his team from the Signal Corps to NASA). As intended when under ARPA management, the satellite would function as a proof of concept for weather support. NASA took on the remaining balance of funds in the weather satellite's budget ($11M) and responsibility for program management.

It's important to note that even if the NASA-WB partners could have had unlimited access to the TIROS I and II data and images, a tremendous amount of work needed to be done in the field of weather forecasting, mapping the images, and computer processing to make *operational* use of the nephanalyses, let alone data. The fields of telemetering bandwidth, data processing, and sheer experience interpreting weather data

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[396] In April, the Department of Navy wrote NASA, notifying them that meteorological interpretation would be performed by the Navy Photographic Interpretation Center, Air Force Cambridge Research Labs, as well as the Weather Bureau. Throughout TIROS I and II, NPIC and military intelligence still approved the release of all images, not just to international partners, but for official USWB forecasting.

[397] RCA had developed the payload for an Air Force reconnaissance satellite in 1955, then, when turned down, made an unsolicited offer to the Army Ballistic Missile Agency for them to have their own reconnaissance satellite. In 1958, this project was transferred to the Army Signal Corps, which was responsible for Army research and development of meteorological instruments.

also had to be improved before the NASA-USWB partners could make *operational* use of a meteorological satellite system.

Vanguard and TIROS: Circulation of Observations

> Particular attention should be paid to preserving and extending the patterns of cooperation which were formed during the IGY…the special committee commends the NASA for establishing an Office of International Cooperation...[398]

Aside from using the same Vanguard and Signal Corps manpower and much of the same support system hardware, another important link between Vanguard and TIROS were the precedents of data circulation and limitation. Four months before the close of the IGY, Weather Bureau Researcher Harry Wexler explained to WB Chief Francis Reichelderfer that twelve months of "International Geophysical Cooperation" would follow the IGY, extending collaborative activities to the end of 1959. This was, "to satisfy both Soviet desire to keep intact their IGY machinery and several nations' need to keep their budget and legislative people happy."[399] In part, this bureaucratic extension of the IGY might be viewed as necessary because the US was the only country that had *instituted* space research in a civilian space program. International partners in a sense, needed an extended "expiration date" to make use of IGY data still being processed and recorded. In addition to the rich return of ground and lower atmospheric observations returned from the IGY, many satellite launch schedules had slipped beyond the formal close of the IGY cooperation, giving added reason to extend the IGY.

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[398] Final Report of the Senate Special Committee on Space and Astronautics. Pursuant to S. Res. 256 of the 85th Congress. 86th Congress, First Session, Senate Report No. 100 March 11, 1959, 28-31. Cited by Galloway in *Reconsidering Sputnik.*
[399] Quote continues stating, "this will mean a new Acad. organization in the States." Since it is capitalized, I presume he is referring to the NAS and not "academic" organization. Wexler to Reichelderfer, 9 August, 1958. Box 9, Wexler Papers.

These latecomers included three US satellites carrying meteorological instruments. Vanguard II, was launched on 17 February 1959, but due to improper orbital insertion, William Stroud's scanning infrared experiment could not collect useful observations. Explorer VI, launched by the Army Ballisitic Missile Agency, on 13 October 1959, produced the first photograph of earth from orbit. The small TV camera on board spent 40 minutes scanning the earth, producing one pixel per satellite rotation, compressed the data, and telemetered it to ground stations. Only one image was reduced from the data. The image was so poor that "any correlation with known weather from the BMD maps was fanciful at best" and at one Washington, D.C. press conference a Goddard Spaceflight Center engineer (perhaps in jest) accused "This is all a fake!"[400] The Army produced no more images for public circulation. Explorer VII carried Suomi's radiation budget experiment. Sources have not yet revealed how the data from the radiation budget experiment might have been distributed, but there was wide dissemination of the narrative and maps that he drew up from the data.[401]

Both of the imaging satellites were, to varying degrees, failures. Although they returned no useful observations of the earth, their originators had set important precedents of plans for data circulation *and* public awareness of it. Awaiting the launch

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[400] "Gideon Marcus, "Earthbound Pioneer (Explorer 6)," *Quest* 19 (2012), 46.
[401] "Radiation Measurements from an Earth Satellite," Explorer VII, XIIth General Assembly International Union of Geodesy and Geophysics, Helsinki, August 1960; "Variability of Solar Constant from Explorer VII," New York Academy of Sciences, January 1961; "Some Meteorological Data Obtained from Explorer VII," American Meteorological Society meeting at Washington, April 29, 1960; "A Simple High Capacity Digital Output Storage System for Space Experiments," Symposium on Electronics and Telemetry, Section IV-V, published in Institute of Radio Engineers Transactions of 1960; "Instrumentation for a Thermal Radiation Budget Satellite," Proceedings of the National Electronics Conference, Vol 15, 1959. "Analysis of Satellite Infrared Radiation Measurements in a Synoptic Scale," *Monthly Weather Review* (October 1961).

of Vanguard II, one newspaper reported to readers that although the satellite had missed its IGY deadline, it was still being treated as an "international scientific experiment in space" with the National Academies of Sciences (not NASA) planning to relay data to all nations participating in the IGY (sixty-six countries at the time).[402] Another newspaper article explained that it would take two weeks before the Army Signal Corps scientists would be able to process data and "reconstruct first space pictures of earth's cloud cover."[403] Given the fact that these were the first images of their kind, it can be hard to speculate how much time the Army factored in for "stitching" images together into mosaics and how much time was necessary to confirm that no strategic assets were *too* visible. The two-week wait for images rendered them useless for weather forecasting purposes, though meteorologists could contrast images with the known weather conditions at the time of imaging and begin refining image interpretation skills.

Due to the fact that the TIROS I and II satellites had never been intended as contributions to the IGY (they had, in fact, emerged from ARPA's plans for military weather reconnaissance) and that the system transferred to NASA so late in development, the armed services exercised considerable latitude determining the processing and circulation of TIROS I and II data. Although NASA and the USWB were project managers and listed as the responsible agencies, in practice, NASA exercised little coordinating power over the space system users.

Thus, as of 29 September 1959, both 35 millimeter film negatives or positives of the television pictures *and* duplications of the magnetic tape from the infrared instrument

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[402] Press clipping, "New Vanguard Lifts 21.5-lb Satellite, 17 February, paper not identified. Record Number 006640 NHRC.
[403] Press Clipping "New Satellite Won't be Lonely: 4 Earlier Ones are still in Orbit," New York Times 18 February, 1959. Record Number 006640 NHRC.

were to be available to "various organizations" willing to write and request copies as of September 1959. By 29 October, NASA and USWB representatives were surprised to learn of important changes to TIROS data dissemination. An officer representing ARPA had recently:

> informed us of an ARPA memo quoting the US intelligence board to the effect that all TIROS photos be reviewed by Intelligence personnel prior to public release. It was further indicated that this applied not only to the output of the narrow angle view camera, but also to that of the wide angle view. Since this was contrary to the planning to date on the utilization of these pictures, a meeting with the DOD Intel personnel was deemed desirable…[404]

Soon after, Wexler wrote a memo invoking his authority as National Academies of Sciences Space Science Board Chair of the Committee on Meteorological Aspects of Satellites. Sending the memo to NASA (presumably to be sent on to ARPA), he recommended that TIROS data be made available "to any scientific group" wishing to study them. Morris Tepper, Chief of NASA's Meteorological Satellite Program commented that "from a pure scientific research point of view, there is no objection to the kind of arrangement proposed by Dr. Wexler and it has our endorsement at the working level."[405]

TIROS I was launched by an Air Force Atlas I on 1 April 1960. On board were three meteorological sensors: two TV cameras and one infrared experiment. Television images of clouds were transmitted on each orbit to receiving stations in Hawaii and near the Army Signal Corps Lab. They were then displayed on a TV screen, photographed with a 35 mm camera, and recorded on magnetic tape. TIROS carried two television cameras on board, one wide angle (imaging a wider swath of the Earth) and one narrow

[404]Memo for Administrator, Dissemination of Meteorological Data from Project TIROS 29 October, 1959, Project TIROS Record Number 6467, NHRC.
[405] Ibid.

angle (imaging a more narrow, but higher resolution portion.) Approximately 500 wide angle camera pictures were going to be selected for photogrammetric analysis by the Navy Photographic Interpretation Center. With their help, NASA would be able to improve estimates regarding camera orientation for each image. The US Weather Bureau was tasked with constructing grids showing geographic coordinates on these pictures and the remaining wide angle images. Gridding the images would make it possible to accurately locate the centers of the cameras, making it possible to identify the swath of higher resolution data within the image of the wide angle/lower resolution camera.[406] Narrow angle images, due undoubtedly to their higher resolution, were classified whereas the wide angle/lower resolution camera produced unclassified images. Nevertheless, members of the intelligence community reviewed *all* images before release to the meteorologists.[407]

The infrared radiation measurements taken by TIROS were reduced to a digital magnetic tape for input in a computer. The USWB received this data from NASA after it had been calibrated. To make sense of the infrared readings, NASA provided orbital information along with vehicle attitude so that all this information could be processed by an IBM 704 computer.

In the months that followed TIROS' launch, the USWB worried that NASA could not keep enough satellites in orbit long enough for sustainable weather coverage. NASA representatives, in turn, invoked their authority as coordinating agency, openly questioning the USWB's ability to process and use such data. One week after NASA's launch, NASA's Hugh Dryden reflected on the USWB's inability to process, store, and

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[406] Ibid.
[407] Ibid.

disseminate satellite telemetry. He opined that the current volume of data was so great that the USWB simply could not deal with it by current processing methods and suggested that the USWB turn to the private sector seeking, "contracts with non-governmental agencies with special competence and experience."[408] Harry Wexler, on the other hand, proposed an international division of labor. Rather than contract with the private sector, he suggested that the USWB contract with other national weather services for the storage and processing of meteorological data, expanding their base of collaborators.[409] On 18 April 1960, NASA Administrator Keith Glennan worried that the six thousand photos returned from TIROS were "almost impossible to cope with."[410]

Might the USWB have been angling for cooperation with the Soviets when they suggested contracting with international partners for data processing and storage? Already, NASA administration and the White House were considering the possibility of inviting the Soviets to trade weather satellite data in "Project Comet." NASA – White House correspondence regarding this was classified as Secret, likely due to fears of premature speculation in the press before the US could decide whether or not it would formally invite cooperation.[411] On 26 April 1960, Administrator Glennan wrote President Eisenhower, updating him on a variety of international cooperation projects taking place at NASA. Glennan noted that due to the fact the USSR cooperated fully with the World Meteorological Organization, "the proposed cooperative US-USSR space project would fall naturally in this pattern." Significantly, he observed that if the Soviets demurred on

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[408] Hugh Dryden to F. W. Reichelderfer, May 6, 1960, Folder General Correspondence, Box 11, Wexler Papers.
[409] Harry Wexler, "Guidelines for Supplemental Request for Satellite Meteorology, R&D" April 8, 1960. folder 1, box 11, Wexler Papers.
[410] Glennan, *Birth of NASA,* 18 April 1960.
[411] Glennan to Eisenhower, 26 April 1960, Record Number 012518 NHRC.

collaboration, “it could be the result of their inability to move rapidly in this field.” While national pride might make them wish to contribute, their refusal to collaborate might either indicate that their technologies were inferior, or, at the very least lead other parties to *presume* their satellites were inferior.[412]

Unfortunately for the USWB, Gary Powers’ U-2 high altitude reconnaissance aircraft was shot down by the Soviet Union on 1 May 1960. Worse, before learning that the pilot had survived, the White House claimed that the U-2 was a NASA experimental vehicle researching the upper atmosphere and that it had gone off course. It took until 9 May 1960 for Glennan to convince his head of International Relations Arnold Frutkin that the Project Comet invitation to trade satellite data would have to wait.[413] Given the intelligence and the armed services communities’ concerns about the circulation of television images that may reveal too much information, might they have permitted sharing TIROS images with their potential adversary? It is probable. On 21 May 1960, Air Force General Thomas Power wrote Air Force Chief of Staff General Thomas White, observing that the TIROS satellite had certainly demonstrated the feasibility of image intelligence from space, but that they were “not entirely suitable for intelligence purposes”[414] The armed services to varying degrees each benefitted from the international circulation of meteorological data.

TIROS Follow-On: Desires for an *Operational* System

Atmospheric sciences stood at the crux of several interagency matters including strategies to secure the maximum amount of funding from the Bureau of Budget, efforts

[412] Ibid.
[413] Glennan *Birth of NASA*, 9 May 1960.
[414] Power to White, 21 May 1960, Box 34, Folder 2-15 SAC, Thomas White Papers.

to streamline redundant research programs, and military demands for weather prediction. This political and financial climate influenced relations among weather researchers, satellite developers, and assorted users of meteorological data and necessitated a close partnership between NASA and the WB. Indeed, both Reichelderfer and Wexler were eager to enlist the technical guidance of NASA. Neither agency posed an overt threat to the other's scientific jurisdiction. As NASA Administrator Hugh Dryden communicated to WB Chief Reichelderfer in May of 1960, "NASA has recognized from the beginning that research in meteorology as such, and the exploitation of meteorological data…are not within the functions assigned to NASA," rather, "NASA does have the function of 'development, construction, testing and operation of research purposes of aeronautical and space vehicles." He continued explaining, "this includes the research on and the preparation and launching of satellite meteorological instrument packages, including data retrieval."

TIROS I's performance received rave reviews from both the military and civilian meteorological communities. However the meteorologists always made it clear that they wanted more. TIROS, launched on a Thor-Abel rocket only had enough thrust to orbit around the equator. Meteorologists were eager to have a satellite in polar orbit which would provide global coverage of the poles (important for forecasting and science) but also coverage of the Soviet Union (of interest to the armed services). The Navy requested that the next TIROS have courier style magnetic Earth orientation so that it had fewer gaps in coverage when the camera was pointing out to space, but NASA said that they could not make those changes to the system in time for the projected 1962 launch of operational weather satellites. The Navy and USWB requested that the operational meteorological satellite be less sophisticated than NASA was planning due to funding constraints. At this time NASA was eager to move on with development of next generation of meteorological satellites (that the Vanguard team had already begun development for in 1959). That fall, they informed the Weather Bureau that they would stop funding the USWB's Meteorological Satellite Section as well as the "experimental operational use of satellite data."

It was at this time that the NAS and UCAR began coming together forming a more substantial contingency to support basic atmospheric research. On 25 September 1960, under the heading "Satellite Effort Could Be Wasted" (a reference to the TIROS weather satellite launched in 1960) the NAS announced the opening of NCAR. Quoting an NAS report:

> there exists at the moment no organization or group in the world that is prepared to exploit fully the new wealth of information that meteorological satellites will certainly provide. Thus, the huge expenditure of scientific effort, engineering, and finances in meteorological satellites may be largely wasted unless a proper organization is ready to exploit the informational output of the meteorological satellites for the increase of our knowledge and the construction of a sound, theoretical foundation upon which a new order of practical forecasting can be based.[415]

While the division of labor between the Weather Bureau and NCAR would evolve over time, as of 1959-1960, NCAR was expected to provide computing facilities to develop techniques in measurement, data reduction, and data interpretation.[416]

NASA and the USWB were still trying to negotiate an amicable division of labor concerning the exchange of data with international partners. In August of 1960, NASA

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[415] "For Release Sunday September 25, 1960" NAS. No title, first subheading is "Satellite Effort Could be Wasted," Folder ORGANIZATION NAS: Committee on Meteorology 1957, NAS.
[416] Blue Book, 39.

and the USWB invited twenty-one countries (likely NATO partners judging by the Project Comet summary of international collaboration) to participate in analyzing TIROS II data. This was billed by the US as a training opportunity for international partners and after TIROS II (which was the second formerly ARPA satellite) NASA and the Weather Bureau extended the circulation of images to WMO partners.[417] On 6 October 1960, Francis Reichelderfer and Hugh Dryden (NASA's Associate Administrator) spoke by phone. Recently, the USWB Chief had written NASA contesting the fact that NASA was imposing on the USWB's mission by transmitting data to international partners. Over the course of the conversation, "the Chief reiterated the Weather Bureau's basic meteorological responsibility and apparently had Dr. Dryden's concurrence that they did not wish to alter this."[418] During the conversation, Reichelderfer came to allow that it was appropriate for NASA to transmit orbital data concerning the satellite, however he stood by the principal that the USWB ought to be the entity forwarding satellite imagery (i.e. meteorological data) to international partners.

Later that week, at an 11 Oct 1960 meeting among Dryden, Wexler, Reichelderfer, and other NASA and WB officials, Wexler again raised the possibility of transitioning to a fully operational satellite system, making every effort to keep at least one satellite in orbit at all times. Dryden responded with sympathy to Wexler's research interests, but an eye on the budget. He allowed that several users demanded such a "beefing up" of the satellite system (presumably the Air Force was the most vocal), but that bottlenecks in the production of Agena boosters had increased the cost of an Atlas-

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[417] Patrick Hughes "Francis W. Reichelderfer, "Part II: Architect of Modern Meteorological Services, *Weatherwise* 34 (August 1981), 148-158.
[418] "For the Record, Notes taken of Chief's side of telephone conversation with Dr. Dryden, October 6, 1960" Box 10, Folder General Correspondence 1960, Wexler Papers.

Agena combination to $7-8 million a set. As a result, one more advantage to extending the development phase on TIROS was to cover for the fact that the USWB lacked the money and NASA lacked the boosters to launch or maintain an operational satellite system—much easier to dub it "experimental" and not have to justify occasional gaps in coverage. Already the Bureau faced the risk of cutting other programs to cover expenses of the weather satellite program.

Furthermore, several parties remained skeptical that the USWB was sufficiently funded or staffed to manage a centralized weather service providing for all branches of the military in addition to civilian applications. Reichelderfer cautioned that their annual appropriation of $500M for satellites and $50M for traditional Weather Bureau functions demonstrated an undeniable shift in priorities.[419] These numbers represented an intimidating expansion of WB operations.

Significantly, Air Force General Yates (functioning as Assistant to the Secretary of Research and Engineering) was displeased with the designation of TIROS as experimental and anxious to speed development to the operational phase. Reichelderfer noted Yates' enthusiasm for enlisting "the Systems Approach" and observed that Yates believed "plans might be moving too fast in the utilization of an R & D satellite for operational purposes, and too slow in the planning for an operational satellite as such." Assuming that the rate of development had been hampered by limited resources, Yates asked whether the Bureau might "get money to finance the *whole* meteorological satellite

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[419] Emphasis in original F. W. Reichelderfer to multiple addressees, "Resume of Conferences on Meteorological Satellites," 11 October, 1960, Box 11, File General Correspondence 1960, Wexler Papers.

program," and make it fully operational.[420] As mentioned above, this would undoubtedly have adverse effects on other USWB research obligations.

Yates feared that the longer NASA and the USWB for all appearances stalled on setting up an operational system, the greater likelihood that the Air Force (Strategic Air Command in particular) would risk gaps in weather coverage. TIROS satellites suffered two sorts of gaps. First, NASA and the WB could not afford to keep weather satellites in orbit year round. Second, the early experimental TIROS satellites were not spin-stabilized, meaning that the machine itself rotated while orbiting the earth. The TIROS satellites I, II, and III cameras spent only a fraction of their useful life directed at earth, meaning that even while a satellite was in orbit, considerable swaths of the globe were missed with each pass.

At a meeting held 17 October 1960, NASA officials indicated that weather satellites were nearly operational and that it was time for another institution to "take over operation and control." Air Force officers interpreted this to mean that the system was up for grabs for either the armed services or the USWB.[421] Similarly, Harry Wexler and his associates at the Bureau found themselves debating their next move. Wexler noted that by ostensibly extending the experimental phase of TIROS weather satellites, the USWB gambled on the possibility of securing more funding from the Bureau of Budget. In an October 1960 memo to his colleagues at the WB, Wexler observed that they stood at a "crossroads" of two options. First, the WB might deem the TIROS satellite system fully

[420] Emphasis added. F. W. Reichelderfer to multiple addressees, "Resume of Conferences on Meteorological Satellites – Dr. Dryden, NASA, General D.N. Yates, DoD," 11 October, 1960, Box 11, Folder General Correspondence 1960, Wexler Papers.
[421] This was General Thomas Power's interpretation of the meeting, in Power to White, 1 December 1960, Box 34, Folder SAC, Thomas White Papers.

functional and operational. This, however, would eliminate NASA from the equation and result in a considerable increase in expenditures for the WB—"at possible risk to its other R & D requests." Alternately, the WB could continue to "split the package" with NASA, allowing NASA to request funding for research on the hardware, while the WB would request funding to operate the system. After several cautious correspondences with NASA's Hugh Dryden (and a bit of awkwardness surrounding accusations of duplicate requests for funding of satellite R & D), the Bureau and the Agency determined that they would for the time being continue to classify the TIROS system as experimental and leave all associated matters of funding to NASA.

What matters here are not the blurry boundaries between delineations of "development" and "operations." Rather, I encourage the reader to focus on the fact that the NASA and the WB together consciously negotiated the status of the TIROS satellite system in such a manner that sustained the viability of their financial and scientific relations. Determining whether TIROS was experimental or operational was less a factor of TIROS I's technical performance and more a function of institutional dynamics: how to secure funding, who best to request funds, and which state (development or operations) they were best equipped to manage. After having framed the issue within these pragmatic demands, NASA and the WB opted to characterize TIROS as an experimental system, still in need of R & D funds, as funneled through NASA.

Concluding Thoughts

Why does the organizational tool of "basic research" seem to stop working in this chapter? In part because, as all the actors are well aware, it is impossible to draw clear distinctions among basic and applied work, military and civilian and this chapter truly is where the rubber is hitting the road on the meteorological satellite policy. The relationship between the USWB, the armed services, and NASA cannot be described as collaboration, nor outright competition. Specifically because the armed services were already equipped to participate in the science services side: collecting data and contributing it to the WBAN, designing meteorological satellites, operating satellites systems, and providing satellite data, military and civilian parties continued collaborating in field research programs into the 1970s (GARP is just one example) and beyond. Thus, the USWB was already very much reliant on the armed services for data from the US and spanning the globe, the civilian meteorological community's best hope was to ratchet up the federal support of and bureaucratic clout of non-military meteorological communities in universities and USWB.

The Air Force becoming dissatisfied with NASA's way of managing the meteorological system is important to note because the Air Force was preparing to "press for control" of the US meteorological satellite system to assure that it would be in orbit as soon as possible. NASA was not entirely at fault for how long it took. TIROS had already been redesigned once so that it could be launched on the Thor-Abel, but Thor rockets had gone up in price substantially, making it harder for NASA to budget for constant satellite coverage. (Launch is by far the most expensive element to space science). Given NASA's desire to move on to more complicated systems and the resistance of the USWB and the armed forces, it makes sense that by 28 November 1960 the DOD and USWB come to the agreement that they prefer to meet under a Joint Meteorological Committee Reichelderfer is already chairing. In this way they side-step NASA influence. At this point, all correspondence with NASA was at higher levels of management.

As potential users of NASA's Nimbus satellite system, the USWB and armed services had common interests: cheap systems, polar orbiting satellites, and operational coverage as soon as possible.[422] In Chapter Six, their mutual interests will result in the Air Force pursuing its own highly classified DMSP, but then persuading the USWB to strong-arm NASA into more light, cheap, non-Nimbus satellites closely resembling the DMSP polar orbiter. This would be dubbed the TIROS Operational System.

[422] See Richard LeRoy Chapman, "A Case Study of the US Weather Satellite Program: The Interaction of Science and Politics," (Syracuse Univeristy, 1967).

CHAPTER SIX
Going Operational: Bilateral Cold Line, Multilateral World Weather Watch

> space science, like nuclear science…has no conscience of its own. Whether it will become a force for good or ill depends on man, and only if the United States occupies a position of pre-eminence can we help decide whether this new ocean will be a sea of peace or a new terrifying theater of war. I do not say the we should or will go unprotected against the hostile misuse of space…but I do say that space can be explored and mastered without feeding the fires of war,[423]
>
> President Kennedy, September 1962

Chapters Three through Five document the transition of meteorological satellites from Vanguard and Explorer proof of concept satellites to TIROS experimental satellites. With this chapter we shift emphasis to meteorology as a science service, employing operational meteorological satellite systems. Here, the same actors from space science and meteorological communities retained hope for the utility of nephanalyses for forecasting purposes as well as data concerning the earth's albedo, heat budget, and other properties. From the outset, Weather Bureau officials anticipated the input of World Meteorological Organization partners who would benefit from US satellite data and images and in return provide local weather observations for establishing ground truth. Science services would progress hand in hand with fundamental research as the data was archived and used in climatological studies or to study phenomena such as typhoons, monsoons, and tornados.

[423] http://er.jsc.nasa.gov/seh/ricetalk.htm, last accessed 5 November 2013.

On 25 May 1961, President Kennedy called for the USWB to be provided funding to develop “at the earliest possible time” a satellite capable of worldwide weather observation (in implicit contrast to the circulation restrictions on TIROS I and II data).[424] Presidential mandate was less an instruction to NASA and the USWB to share satellite observations with international partners and more a signal to other nations of American readiness to invest resources in global weather services. President Kennedy and Vice President Lyndon Johnson viewed this, and the Apollo mission announcement made the same day, as a solution to new crisis to US legitimacy. In the weeks following the successful orbit of cosmonaut Yuri Gagarin, human spaceflight and space applications such as communications and weather satellites were intended to buttress the US’s faltering reputation as a peaceful and potent space power.[425] It is debatable the degree to which Cold War statesmen sincerely hoped that the Soviet Union would collaborate in a global weather service. Indeed, from the outset, the Kennedy administration engaged in what are generally accepted as half-hearted offers to collaborate on projects ranging from a joint lunar base to trading data and research in joint working groups.[426]

The space science community in NASA and the meteorological community translated these Executive level priorities into science practice. To experts such as

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[424] Urgent National Needs Speech, here the President also announced the US intention to place a man on the moon. http://www.jfklibrary.org/Asset-Viewer/Archives/JFKPOF-034-030.aspx, accessed 8 November 2013.
[425] One excellent example of this mindset is a 12 April 19 1961 (the day of Gagarin’s launch) press conference in which Kennedy emphasized the US’s strong suits as being “more long-range benefits to mankind,” these were “not as spectacular as the man-in-space or the first sputnik, but they are important.” Logsdon, *John F. Kennedy,* 71.
[426] Edward Clinton Ezell and Linda Neuman Ezell, *The Partnership: A History of US-Soviet Cooperation in Space* (University of Miami: Center for Advanced International Studies, 1974); Krige, *NASA in the World;* Matthew von Bencke, *The Politics of Space: A History of US-Soviet/Russian Competition and Cooperation in Space* (Boulder, Colorado: Westview Press, 1997).

Reichelderfer and Wexler, international leadership meant setting an example of reciprocity with international partners. Relationships were characterized as reciprocal because the utility of satellite observations relied on routine global data from international partners. In making this offer for exchange, they provided a justification for national weather services abroad to expand and improve upon their own operations.

International Collaboration: Geographic and Intellectual Reach

On the three-year anniversary of the successful Vanguard I launch, the former lead of the Program John Hagen delivered a speech to the National Rocket Club.
At the time, Hagen was serving as NASA's Assistant Director for Spaceflight Development. This one man's career in many ways functioned as an analog to the evolving US space program. Beginning as an astronomer at Wesleyan University, Hagen transferred to the NRL in 1935 and worked as a radar physicist in the Second World War. Postwar, he worked alongside UARRP collaborators and the Project Paperclip engineers and scientists, sharing data and observations with UK space scientists in the early 1950s, and weighing in on the deliberations to form a civil space program in 1957-58. Hagen was one of many researchers-turned-administrator who had contributed continuously to the US's fitful emergence as a space power. In his speech, he observed that the US was already benefiting from a rise in the number of experts worldwide contributing to space research and exploration. The next step, he predicted, would be the simultaneous and ordered observation of upper atmospheric phenomena from a variety of geographic locations, followed by the free interchange of such data. Was he hearkening to the IGY past or foreshadowing WWW coordination?

To Hagen, the IGY Minitrack network engendered "perhaps the simplest type of international cooperation… sharing in the worldwide tracking of space objects." [427] Minitrack was only the beginning. Hagen spoke that day of both intellectual access and geographic access accomplished through international cooperation. In addressing the limitations of US spaceflight capability, Hagen— born in Nova Scotia— evoked the notion of a worldwide pool of human and material resources available to the US. He argued that it would be "morally wrong" to "carry on the work of science" without making the most of the talent of foreign scientists desiring to participate in space research. Both the space science community and the meteorological community had practical needs to be filled through coordination with international partners.

"Data Sparse Regions"

As mentioned in previous chapters, the USWB faced a number of interrelated challenges and objectives in operating meteorological satellites: improving world meteorological service, improving the fundamental understanding of the Earth's atmosphere, and gathering more data from a finer grid of locations. Representatives of the military-civilian Interdepartmental Committee on Atmospheric Sciences (ICAS) explained: "Without these basic measurements of the atmosphere, scientific research, as well as operational weather forecasts and warnings, will suffer severely." In October 1960, members of the ICAS learned that the Air Force Weather Reconnaissance Program

[427] "Space and Cooperation," Hagen, Director of Office for the UN Conference, Speech to national Rocket Club March 1961, RN 902 LEK 1/8/3 Hagen bio, NHRC.

would phase out by the close of 1963, depriving the USWB of weather data from across the globe.[428]

This situation sent ICAS members scrambling to find a new plan for procuring conventional weather observations from oceans and "sparse data regions." In response, the ICAS composed "A Plan for Meeting Meteorological Observation Requirements over Sparse Data Regions." In it, the they expressed concern over the USWB's ability to procure adequate meteorological data from oceans and other "remote regions of the earth." The report continued, noting that, "[t]his problem has become increasingly urgent as a result of an announced plan by the Department of Defense to phase out the Air Force Weather Reconnaissance Program." Noting that the AFRP had already been cut by 40%, the report recommended that an alternative be set up by December of 1963—the date by which the Air Force would complete the phase out of its ground weather services.[429] Realizing that this lack of data would adversely affect research as well as weather forecasts and warnings, the WB began looking into upper air sounding equipment that could be used on merchant ships as well as automated meteorological observing stations for ground and sea.

Although the bland terminology of being "data sparse" emotes images of open international waters or desert wastelands, forecasters and researchers alike desired more and more standardized reports on weather phenomena. While the Soviet Union was a reliable contributor to the World Meteorological Organization, there were several

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[428] Draft: Plan for Meeting Meteorological Observation Requirements over Sparse Data Regions, 13 October 1960. Box 11 Wexler Papers. Also, Resume of Conference on Meteorological Satellites, 1 October 1960, Box 11, General Correspondence 1960 Wexler Papers.
[429] Ibid.

countries incapable or unwilling to contribute. China, occupying a very large landmass, and not contributing to current international weather exchanges was just one source of concern.

Such data would also benefitted the armed services—in particular Strategic Air Command and other departments of the Air Force and Navy responsible for in-air refueling over uninhabited regions and open stretches of water. Presuming the likelihood that their Cold War adversary would deny the US weather observations in the event that they discovered the US conducting satellite reconnaissance, Air Force leadership reasoned that they ought to orbit meteorological satellites to compensate for the potential loss of Soviet weather reports. On 1 December 1960, SAC Commander in Chief General Thomas Power wrote USAF Chief of Staff, General Thomas White. Reflecting on SAC's dependence on Soviet weather observations and the likelihood that the USSR would deny weather observations of the US upon discovering the use of image intelligence satellites, Power requested that the USAF undertake the operation of its own meteorological satellite system or "press for control" of the national meteorological satellite system "if we are to insure that the output from the system will satisfy our requirements." The outlook of General Power warrants quoting at length:

> With the success the Russians had in exploiting the U-2 incident, it appears logical to assume that with our launch of reconnaissance satellites, Russia will again exploit any means to degrade the effectiveness of the system and at the same time reap the harvest of propaganda. Since [the photographic reconnaissance satellite] SAMOS will be dependent on cloud conditions…it appears only reasonable for Russia to deny the free world weather data from the Sino-Soviet bloc. This action would not only have an immediate and serious effect on our ability to provide weather forecasts for the operation of SAMOS, but would provide Russia with a tremendous propaganda drum, for all nations are

> interdependent upon one another in their endeavor to understand and predict the actions of the atmosphere.[430]

Indicating it was common knowledge that the USWB was underfunded, he stated that it was "in a very poor position to obtain funds to support the [satellite] system, and was sure they would not have the same interest in the program as we will have." A few days later, General Power wrote White, suggesting that the Strategic Air Command change its name to Strategic Aerospace Command. SAC was intended to be the operating agency for the Air Force reconnaissance satellite and Power already was considering the adoption of the TIROS meteorological satellite system from NASA (presuming it would even be allowed). In light of this, Power suggested that the name change would benefit the Air Force, buttressing its reputation "as the progressive and farseeing arm of the military services," this, in turn, would "firmly identify SAC as the air/space agency for the accomplishment of the strategic war mission [sic]."[431]

1961 Plans: National and International

Users in the defense and civilian meteorological communities were eager for follow-on satellites after TIROS I and II. After resisting the notion of having two satellite systems—Nimbus and TIROS—in design and production at once, NASA representatives finally relented to plans for follow-on TIROS satellites. Reichelderfer and Wexler remained eager to continue coordinating efforts with NASA. In the eyes of the USWB, NASA's cache of technical skill and design experience coupled nicely with its rapport

[430] Power to White, 1 December 1960, Box 34, Folder SAC, White Papers.
[431] Confidential letter from Power to White, 5 December 1960. Box 34, Folder SAC, White Papers.

with Congress; NASA assured a higher degree of financial security and political credibility. Observed Reichelderfer:

> As for…whether NASA or Weather Bureau should budget for TIROS V, VI, and possibly VII, I would be inclined to say that NASA should go head solely because they have Congress' ear on satellites and are more likely to get the money in crash estimates; moreover; this will give us more time to get Congress and Budget acquainted with the importance of meteorological satellites and the fact that NASA and everybody else agree that operational satellites are not the function of NASA.[432]

With the Nimbus National Operational Meteorological Satellite System running behind schedule, these follow-on TIROS satellites would fill in gaps in coverage. Later, that month a confidential NASA memo observed the importance of sustaining the TIROS program.[433] The memo observed that, "Not only does it stand on its own feet in this sense but it would also act as an example and, therefore, as a 'prop' to our other programs," buttressing morale and setting an example of project management. Thus, an additional $24M was requested "at once" so that NASA could begin placing orders for payloads and launch vehicles. If no additional funds could be obtained from Congress, the memo advised reprogramming other existing projects to free up the money.

In spite of the fact that NASA retained the franchise to establish requirements for a joint weather satellite system, in the summer of 1961 meteorological satellite planning again diverged into military and civilian programs. The Air Force, unsatisfied with the fact that TIROS satellites would not be equipped with spin stabilization (which would eliminate the gaps in photo coverage addressed in Chapter Five), and that it would not circle the earth in a polar orbit, had begun pursuing its own classified weather satellite

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432 F. W. Reichelderfer to multiple addressees, "Duplication in NASA and WB Submissions to BoB," 6 March, 1961, Box 12-13? Wexler Papers.
433 Some Notes on the Relationship of NASA-DOD Space Programs, 19 April 1961 Record Number 11167 NHRC.

system.[434] With no redundant systems on board, the Air Force weather satellite was lighter and could be launched on a smaller, cheaper rocket. Also, a polar orbit guaranteed full coverage of the Soviet Union, Arctic, and Antarctic. This development is significant because parallel development of military and NASA satellite would provide an off-the-shelf alternative to NASA's Nimbus system as it came to fruition.[435]

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[434] The National Reconnaissance Office history of the DMSP program indicates that NASA management remained skeptical that spin stabilization could be developed soon and inexpensively. Cargill Hall, *A History of the Military Polar Orbiting Meteorological Satellite Program* (National Reconnaissance Office, 2001), 2.

[435] Thus, the USWB would insist that TIROS 9 and the TIROS Operational System be based on Air Force models, cheaper than Nimbus but spin-stabilized and polar-orbiting. On 28 September 1965, the DOD and DOC would sign an agreement to eliminate the necessity for coordination between "Aeronomy" and "Meteorological Reconnaissance Programs," formally permitting independent programs. Hall, *History of the Military Polar Orbiting,* 15. Other names include: Weather Reconnaissance Satellite—Program II (as of summer 1961), Program 35 (as of September 1961), Program 694 BH (as of July 1962), Program 417 (as of August 1962). In 1965 the military meteorological satellite program was transferred to SAC and its classification level was reduced. First Defense Meteorological Satellite Program satellite launches 1/19/1965.

Table 6.1 NASA-USWB Satellite Milestones

Satellite	Launch Date	Hardware Notes	Policy Notes
TIROS 1	4/1/60		
TIROS 2	11/23/60		
TIROS 3	7/12/61	New Suomi ERB, switched to two wide-angle cameras, coverage more important than resolution	Launched with MIDAS 3 "Spy in the Sky" accusations
TIROS 4	2/8/62		4/15 begin daily fax of images overseas; suspicion Soviets hacked into system
TIROS 5	6/19/62		
TIROS 6	9/18/62		
TIROS 7	6/19/63		For hurricane/typhoon season coverage
TIROS 8	12/21/63	First APT	First APT
NIMBUS 1[436]	8/28/64	NASA R&D satellite: Advanced Vidicon Sys, APT, high-res IR for night images	1963 cancelled plans to make NIMBUS joint operational satellite system; ESSA/TOS cheaper and less complex
TIROS 9	1/22/65	Wheel mode from DMSP, sun synchronous orbit	April 1965 delivered 2100 storm bulletins to 50 countries
TIROS 10	7/2/65		
ESSA 1/TOS[437]	2/3/66	Satellite was based on TIROS 9	
ESSA 2/TOS	2/28/66	Satellite was based on TIROS 9, APT on all even-numbered satellites	

436 Formerly the NOMSS system, by fall 1962 delays were serious.
437 TOS: TIROS Operational System.

Talking about the Weather: US-Soviet Relations

On 12 April 1961, the Soviets successfully placed cosmonaut Yuri Gagarin in orbit around the earth. President Kennedy initially responded in a fashion parallel to Eisenhower's response to Sputnik, offering lukewarm congratulations to the Soviet Union, but not suggesting change to the US course or policy in of space exploration. At one press conference, he even suggested that US progress in seawater desalinization could "really dwarf any other scientific accomplishments." Facing criticism for inaction from Congress and the press, by the evening of 14 April Kennedy's outlook had begun to change. [438] On 25 May 1961 Kennedy made his "Urgent National Needs" speech to Congress in which he called for four things: the commitment to land a man on the moon (no estimate of cost), an additional $23M funds for the Rover nuclear rocket (to be used for interplanetary spaceflight), an additional $50M for "leadership by accelerating the use of space satellites for world-wide communications," and an additional $75M ($53M for the USWB) for the "earliest possible" worldwide weather satellite system.[439]

On 20 December 1961 the UN General Assembly passed Resolution 1721. Based on a 1960 US State Department Report, Resolution 1721 was in many regards a nod toward US interests in the international use of space.[440] "Believing that the exploration and use of outer space should be only for the betterment of mankind and to the benefit of

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[438] John Logsdon, *John F. Kennedy and the Race to the Moon* (New York: Palgrave Macmillan, 2010), 70-72.

[439] http://www.jfklibrary.org/Asset-Viewer/Archives/JFKPOF-034-030.aspx, accessed 13 November, 2013.

[440] "Position Paper for US Participation in Legal Subcommittee of UN Committee on the Peaceful Uses of Outer Space" suggested the manner in which UN law might be crafted to advance US intersts in space. Its three main proposals were that the committee be re-invited to analyze the legal problems of space, that celestial bodies be exempt from national appropriation, and that nations be required to register spacecraft with the UN. von Bencke, 49.

States irrespective of the stage of their economic or scientific development," the UN resolution suggested that the WMO study methods for advancing weather forecasting capabilities and to "help Member States make effective use of such capabilities."[441] US representatives had seen to it that weather and communications satellites were central to the resolution—two technologies US policymakers were confidant they had a lead in.

With the responsibility to help member nations produce and use weather information came the implicit mandate to suggest amendments to the WMO's existing budgetary and organizational structures. These responsibilities were delegated to Harry Wexler and Professor V. A. Bugaev of the Soviet State Committee on Hydrometeorology. At the USWB, the Resolution set in motion a dizzying chain of events. Aware of Soviet Premier Khrushchev's fickle nature in cooperative agreements, the Kennedy Administration pressured the Weather Bureau to act quickly: draft a plan for the sharing of meteorological satellite data and negotiate it as quickly as possible. Noting the sense of urgency, Wexler observed that the WMO's tasks and timetable were "rather severe." In January of 1962, Wexler met with Secretary General of the WMO to advise on the first draft of the agreement regarding the Greenbelt to Moscow "Cold Line" facsimile line. Yet, rather than simply discuss how best to send satellite data between the two countries, Wexler identified an additional objective: to "fill in gaps" of coverage. He observed that the next steps were "obvious." After coordinating satellite activities, the they would address "more serious gaps in the world network of rawinsonde and oceanic

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[441] "Resolution Adopted by the General Assembly 1721 (XVI). http://www.oosa.unvienna.org/oosa/SpaceLaw/gares/html/gares_16_1721.html, last accessed 13 November, 2013.

surface stations, improved telecommunications, etc—all comprising a global observing and prediction system called the World Weather Watch.[442]

When Harry Wexler and his colleague V. A. Bugaev met in 1962 to draw up their technical plans for the Cold Line - World Weather Watch, they based their planning on two deficiencies in the existing international meteorological system. First, they voiced displeasure with the number of stations contributing ground observations to the WMO. Second, they wished to improve the techniques and instruments for the systematic measurement of the atmosphere above 30 km. Researchers hoped to make better sense of high altitude data (between 30 and 100 km) by combining information gleaned from sounding rockets with satellite observations.

"The First Report of the WMO on the Advancement of Atmospheric Science and Applications in Light of Developments in Outer Space" made it clear that such observations were necessary for NASA and USWB techniques in data analysis and forecasting.

> full exploitation of the new meteorological [satellite] data…necessitates an expansion and rearrangement of the present system whereby conventional meteorological observations are made and exchanged under procedures laid down by WMO…this proposed system which combines satellite and conventional observations, would be called the World Weather Watch[443]

Far from an act of aid to the developing world, enactment of the WWW was quite explicitly intended to advance meteorological satellite practice by "filling in the main

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[442] Harry Wexler to Joseph Kaplan, 4 July 1962, Box 13-14?, General Correspondence File, Wexler Papers. Emphasis in original.
[443] "First Report of the World Meteorological Organization On the Advancement of Atmospheric Sciences and Their Application In Light of Developments in Outer Space" Box 9, Folder 1, Reichelderfer Papers.

gaps in the world network of conventional data."[444] In exchange, the Superpowers ensured availability to all partner nations of processed information, observations, and "satellite data best suited to meet [their] ends."

Part of the impetus for the Cold Line-WWW data exchanges was the cancellation of the Air Force Weather Reconnaissance Program discussed at the opening of this chapter. Thus later, when representatives of the Soviet Hydromet expressed concerns over the January 1964 deadline for Cold Line exchanges, NASA's Hugh Dryden demurred on an explanation, indicating that pressure to impose this deadline came from elsewhere (outside NASA or the USWB). He offered only the ambiguous response that, "one of my problems in my country will be to show exchange of data before 1964."[445] Even if the Soviets did not have a satellite in orbit by January 1964, they did agree to begin sending *conventional* weather data immediately, as soon as the line was in operation. The two nations began exchanging non-satellite weather observations in October of 1964.

In terms of multilateralism, whereas the meteorological community emphasized the contributions other nations could make to the WWW and the improvement of WWW service, statesmen emphasized the service being provided to fellow WMO members. In a 7 March letter to Khrushchev, Kennedy speculated that they could render "no greater service to mankind" than with such a weather satellite system. Khrushchev responded,

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[444] Ibid.
[445] Harry Wexler, personal notes used at Bilateral Talks 30 May 1962, Box 13-14, General Correspondence, Wexler Papers.

agreeing that precise and timely worldwide weather prediction "would be still another important step on the path to man's subjugation of the forces of nature."[446]

Cold Line Planning | World Weather Watch Planning

Representatives of both countries recognized the rhetorical value of cooperating on "practical" space applications such as communications satellites, navigation, search and rescue, and the weather. Such applications promised to improve the quality of life at home or to demonstrate developmental altruism abroad. Thus, weather satellite collaboration was situated among a variety of proposals President Kennedy made before the UN on 20 September 1963.[447] Among his considerations were a World Health Organization center for health communications, regional research centers to train new scientists and doctors for "new nations," a global communications satellite system, a global weather satellite system, a worldwide program for pollution studies and resource management, and finally, a worldwide program of farm productivity.

Academician in the Soviet Academy of Sciences Anatoly Blagonravov shared this rationale, insisting that space experts focus "initial cooperation in practical fields, such as weather satellites and communication systems," particularly because they would be "meaningful to the main in the street."[448] In this, the Superpowers communicated a sense of accountability to populations worldwide. Numerous trade articles promised lifesaving weather predictions regarding tornadoes and hurricanes, improved understanding of worldwide rainfall and monsoons, and the ability to trace radioactive fallout in the event

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[446] John Logsdon, ed, *Exploring the Unknown: Selected Documents int eh History of the US Civilian Space Program Volume II: External Relationships* (Washington, D.C.: NASA History Office, 1996), 148 and 151.
[447] http://www.presidency.ucsb.edu/ws/?pid=9416, accessed 8 August 2013.
[448] "Record of the US-USSR Talks on Space Cooperation March 27-30, 1962. Logsdon, ed. 153.

of atomic explosions. Information and predictions derived from the WWW promised to aid in search and rescue, facilitate ground transportation, predict spring thaws, to make the fields of commercial aviation and maritime industries more safe, and to aid farmers the world over in the timing of planting and harvest. WWW representatives even promised to advance the budding fields of climate and weather modification, to destroy hurricanes, dissipate fog, and bring rain on command.

The US meteorologists emphasized time and again that satellite networks would not immediately render conventional ground observations obsolete. Instead, the development of these space systems relied upon expanding observation and reporting systems on the ground or on suborbital sounding rockets. In the interest of filling in the data sparse regions, the WMO Economic and Social Council adopted Resolution 829 unanimously. At minimum, the WMO called for 100 automated surface stations, 30 in the northern hemisphere and 70 in the southern hemisphere. It recommended the construction of 53 new upper air observing stations, 33 on land and 20 on ships stationed at fixed locations.[449]

In order for such tremendous amounts of information to be useful, local weather conditions had to be quantified: rendered stable, standardized, mobile, and combinable. Stability was attained through durable media and internationally recognized archival repositories; mobility derived through standardized forms, international telephone lines, facsimile, computer lines, and eventually communications satellites. Compatibility of data was achieved by virtue of its standardization in metrology and reporting formats.

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[449] Harry Wexler, "Global Meteorology and the United Nations," *Weatherwise* 15 (Aug 1962).

This was the power that Reichelderfer and the USWB wielded. Returning to notions of a systemicity among US R&D institutions: Reichelderfer did not command the same the influence nationally that he experienced abroad. At home, the USWB had long suffered accusations of not being progressive enough in methods or politics. The FAA, NASA, and the armed services all competed with the Bureau in the field of basic meteorological research, pressing for the decentralization of US R&D management.[450] In March of 1963, Reichelderfer observed that the USWB had been largely "'dealt out of the picture' as being 'negative and unimaginative'" with US research policy.[451] In the US, the Weather Bureau's relative influence was viewed as negligible. On the world stage of the WMO, it was historically and geographically unrivaled.

Public Diplomacy

In October 1966, President Lyndon Johnson's Secretary of State Dean Rusk circulated a paper to the Members of the Space Council. One of the first considerations in the report fell under the heading "Changing International Attitudes." The report speculated that following lunar landings by the US and Soviet Union and the eventual entry of other nations into space, enthusiasm for space spectaculars would undoubtedly diminish. The industrialized "haves" and less developed "have nots" alike would begin to question, "what's in it for us?" Meantime, attention would shift from space spectaculars to "practical applications of space programs."[452] Questioning whether the US should

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[450] Note for Background Views on BOB Report on Meteorological Activities and FAA Critique, 2 March 1963 Reichelderfer Papers,
[451] Reichelderfer to Office of International Meteorological Plans, UN Position on Development of Atmospheric Sciences and Outer Space (UN Res. 1721), 2 March 1963, Box 7, Folder 8, Reichelderfer Papers.
[452] "Space Goals After the Lunar Landing," October 1966, 3. Record Number 14462, NHRC.

move away from an extension of the space race and toward a more orderly and internationally responsible way of doing business, the report suggested that the US "might instead…use satellites to help bridge the 'have' versus the 'have not' gap."

To a limited degree, one might interpret the reciprocal arrangements of the WWW as a manifestation of power by developed nations over developing nations. WMO member states approached the WWW with disproportionate budgets and technical assets, at times conscribed, at times mobilized by Cold War and post-colonial sensibilities. The US and Soviet Union staged space exploration as a transnational activity rooted in global science "for the benefit of all mankind" (a frequent refrain in national and UN law, treaties, and proclamations). This was to their geopolitical benefit. In particular, the rhetoric of space science conducted for the benefit of all mankind shaped international opinion and in turn, space law. Arnold Frutkin, NASA's Director of International Programs, explained in bald candor that the US's image as a progressive and inclusive leader in scientific affairs "without question lent credibility to our posture and contrasted sharply with our competitor's performance." He says this because the US benefitted from positive international opinion throughout the Cold Line-WWW planning and throughout the process of establishing international space law.

Peaceful cooperation—almost as important as the *appearance* of wanting to cooperate—ultimately buttressed the US's image "as an open society ready to join with all of good will, and in particular demonstrates the openness of this country with one of its greatest national assets—advanced technology." These circumstances combined again, in Frutkin's own words, to function as a "catalyst for sentiment in support of US objectives on the subject of outer space in UN forums."[453] Hence, the 1966 settlement of space law as being free for all nations, open for private business, and only mildly regulated by the UN.

In the early years, the US and USSR used the forum of the United Nation's WMO to set the tone for agreements in worldwide standards of data recording and exchange among dozens, and later hundreds, of participants.[454] Through agreements made with the

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[453] Frutkin, 78.

[454] As of January 1, 1976, this list included all members of the UN World Meteorological Organization plus Maldives and Malta, which operated APT terminals but were not WMO members: Afghanistan, Albania, Algeria, Argentina, Australia, Austria, Bahamas, Bangladesh, Barbados, Belgium, Benin, Bolivia, Botswana, Brazil, Bulgaria, Burma, Burundi, Cambodia, Cameroon, Canada, Cape Verde, Central African Republic, Chad, Chile, People's Republic of China, Colombia, Comoros, Congo, Costa Rica, Cuba, Cyprus, Czechoslovakia, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Ethiopia, Finland, France, Gabon, German Democratic Republic, Federal Republic of Germany, Ghana, Greece, Guatemala, Guinea, Guyana, Haiti, Honduras, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Ivory Coast, Jamaica, Japan, Jordan, Kenya, North Korea, South Korea, Kuwait, Laos, Lebanon, Liberia, Libya, Luxembourg, Madagascar, Malawi, Malaysia, Maldives, Mali, Malta, Mauritania, Mauritius, Mexico, Mongolia, Morocco, Mozambique, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Romania, Rwanda, Saudi Arabia, Senegal, Sierra Leone, Syria, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda, Union of Soviet Socialist Republics, United Kingdom, United States, Upper Volta, Uruguay, Venezuela, Vietnam, Yemen Arab Republic, Yemen People's Democratic Republic, Yugoslavia, Zaire, and Zambia. As listed in Library of Congress Science Policy Research Division, *World Wide Space Activities: National Programs Other Than the US and Soviet Union; International Participation in the US Post-Apollo Program; International Cooperation in Space Science, Applications and Exploration; Organization; and Identification of Major Policy Issues.* Report prepared for the Subcommittee on Space Science and Applications of the Committee on Science and Technology, US House of Representatives, 95th Congress, first session by the Science Policy Research Division Congressional Research Service, LOC, September 1977. (Washington: US Government Printing Office, 1977.), 429.

WMO, the USSR and US agreed to use their meteorological facilities, "as places of 'on-the-job' training" and training seminars.[455]

Getting to the Global

Following its rocky developmental phase, World Weather Watch qualified as an unquestionable scientific and public service success. One of its most striking features remains the sheer number of weather stations linked to one another through meteorological satellites, communication satellites, high-speed data processors, and telecommunication facilities throughout the course of the entire cold war. WMO member nations participated in a remarkably smooth-operating system. As of 1975, only five of approximately 135 countries failed to supply weather data in compliance with WWW procedures, and only an estimated 5% of required information remained unreported overall.[456] In the 1970s, WWW precipitated several specialized observational experiments in which nations conducted synchronized observations of extraordinary weather phenomena such as monsoons and polar air-mass transformations. Throughout this time, Soviet and American satellites remained vital tools to the WWW, not only for gathering meteorological information, but later as data relays, transmitting signals from ships, buoys, aircraft, and weather balloons.[457]

The WWW was also a diplomatic achievement. The US and Soviet Union were each dependent upon the developing world for local reports—not only for daily conventional weather predictions, but for the very development of satellite meteorology

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[455] WMO, *World Weather Watch: The Plan and Implementation Programme,* (Geneva: Secretariat of the WMO, 1967), p. 13-14.
[456] Edith Brown Weiss, "International Responses to Weather Modification," *International Responses to Technology* 29 (Summer, 1975), 812.
[457] It was not until the late 1970s that European and Japanese space programs were financially and technically equipped to contribute satellites to WWW.

technique and computer numerical forecasting. Here, the desires of the "haves" and "have nots" converged in the interest of a thoroughly standardized global network distributing satellite and conventional weather data. Together national and international institutions sought to expose budding weather services to higher standards of practice, meantime agglomerating national services into a semi-automated international network geared for the collection and dissemination of world weather data. Infused with a humanitarian rhetoric of development, they offered the legitimacy of WMO training, bargain-priced Automatic Picture Transmission (APT) equipment, and access to satellite data. In the end *all parties* received standardized weather data, training, and forecasts in a politically palatable manner.

CHAPTER 7
Conclusions and Looking Ahead:
Leadership of a Divided World

Cold War historians have produced a rich literature concerning the state's mobilization of technologies in military activities, in international relations, and in politics. Problematizing the notion that space exploration represents solely nationalistic aspirations, I look to the careers of experts within the space science and meteorological communities to document the emergence (not the deployment) of a series of sounding rocket and satellite systems during the Cold War. Charged with maintaining a strategic edge over potential adversaries, researchers in DOD labs pursued programs in materials science, rocket science, environmental science, and space science as just a few examples throughout this study. Thus, the TIROS Genealogy in Table 1.2 and the coalitions listed in Table 1.1 illustrate that the TIROS satellite system traces its origins to a broad network of R&D communities funded almost entirely by defense funding.

Operating at the epistemic edge of their fields—in many regards beyond the budgets of their traditional sponsor-patron relationships—UARRP members mitigated the cost of expensive sounding rocket systems by coordinating research activities with partners in universities, industries, and colleagues overseas. For more than a decade before the Sputnik shock and alleged birth of the Space Age, these researchers in many regards bided their time, waiting for the resources to perform satellite R&D. During this understudied lead-time to satellites, they awaited sponsorship, continuing proof of concept work with sounding rockets (Chapters Two and Three) and weighing the institutional and administrative liabilities presented by satellites (Chapter Three). One month into the IGY and one month before the launch of Sputnik, NRL's Homer Newell published his report, "The Challenge to the United States Leadership in Rocket Sounding of the Upper Atmosphere," cautioning that US ought not lose its lead in upper atmospheric research to other nations.[458]

Funding for a scientific IGY satellite and the Executive mandate for the formation of NASA were two critical moments in which resources otherwise inaccessible to these communities became available. Both tipping points hinged on sobering threats to US national security and the perception that the US may have lost its strategic edge over the Soviet Union. Whereas the IGY satellites were intended to establish the legal precedent of satellite overflight (making way for reconnaissance satellites to better assess the nuclear capabilities of the Soviet Union), NASA was formed in response to Sputnik as an alleged demonstration of Soviet ICBM capability and the threat of a Soviet conquest of space for militaristic purposes. In Chapter Six, cosmonaut Yuri Gagarin's successful orbit around the earth provides a third "threat," a threat less to US national security and more to soft power prestige. In response, President Kennedy called for a race to the moon and funding for what USWB and WMO representatives would mold into the WWW.

Fundamental scientific research, the research communities proper, and manifestations of their R&D such as the Vanguard and TIROS satellites were each dual use in nature. As such, they could serve hard power national defense. But they could also and function as co-optive instruments of soft power among allies (such as the Gassiot Committee, IGY, NASA, and WWW), the non-aligned (through the IGY, NASA, and WWW), and even the USSR (IGY, NASA, and WWW). From roughly 1957 and through

[458] Cited in Newell, *Beyond,* endnote 23, 459,

1962, US administrative and legislative branches began to retool for the more effective deployment of soft power in space. To do so they appropriated pre-existing initiatives (some may say the norms) of scientific and engineering communities. Representatives of the Weather Bureau, department of defense labs, universities, and private industry had each long-since identified stakes in the *carefully managed* circulation of knowledge among themselves and international colleagues. These communities relied upon transnational organizations such as the UN's meteorological, astronomical, radio, and other Scientific Unions to remain abreast of—and to assert their authority in—these fields.

When history is told from the perspective of Stroud, Wexler, Newell, and Reichelderfer's R&D, field science, and science service communities we learn the ways in which NASA was not simply a demonstration of American prowess *vis a vis* Sputnik. Neither can it be described as a clear-cut compartmentalization of civilian resources from military resources. It was at once a compliment to hard power and an instrument for *scientifically substantive* international collaboration.

At the heart of NASA's formation and each the coalitions listed above were efforts to draw distinctions between what were to be military activities, what would be preserved as non-military, or what must be cleaved out as explicitly civilian. Engaging in a Cold War competition with Soviet statism, experts and policymakers of the Eisenhower era expanded federal powers, institutionalizing technological change for state purposes. But many did so self-consciously, fearing the buildup of what was often described in actor terms as a monolithic technocratic state. They deliberated over delicate boundary-work to characterize this expansion of state power as embodying select elements in a series of binaries including: military/civilian, applied/ basic, national/international interest, R&D/operational, crash project/sustainable program, and competitive/collaborative. Thus, rather than characterize their public policy as a wholesale centralization of power in the state, it was viewed as a subsidy to civil life and a counterpoise to the US's much-feared progression toward a garrison state.

I will close this dissertation outlining areas I intend to improve upon in the future. Foremost, I must develop a firmer grasp of the USWB and its relative stance with UCAR, NCAR, and university researchers. I must better elucidate the function of the USWB as a potential and established user of weather satellites and I must also better determine its alleged mandate over basic research to which Reichelderfer and Wexler so frequently referred.

In the months to come I will work to identify numbers reflecting the relative funding of the communities at hand. That will provide a clearer sense of the relative strengths and weaknesses of the institutions as well as their relative rise and decline in influence among one another.

In addition to this, I hope to develop a more refined understanding of the relationship of Eisenhower to the PSAC and how they operated as a conduit of the broader scientific community's interests. I also need to develop a more clear narrative concerning space policy in the Kennedy-LBJ White House years. Doing so will help me begin to refine our understanding of the US and Soviet Union as Cold War powers within a distinctly *global* Cold War.

Finally, this dissertation has explored how scientific communities with the Executive and Legislative branches are interdependent for political legitimacy, public diplomacy, funding, and the execution of public services. However, science and technology policy underpinning these coalition activities were neither inevitable outgrowths of this democratic capitalist system, neither were they guaranteed to be permanent. In later iterations of this work, my research will address threats to the WWW order, in particular, debates concerning the centralization of military and civilian weather satellite programs into one joint satellite system, the unpalatability of the armed services benefitting from the WWW, and how Cold War and post-colonial tensions otherwise influenced the network's operation.

APPENDIX A
Meetings of Rocket and Satellite Research Panel[459]

Meeting	Date	Place	Remarks
0	16 Jan. 46	NRL	Preliminary, exploratory discussion.
1	27 Feb.46	PU	Organizing meeting.
2	27 Mar. 46	NRL	-
3	24 Apr. 46	NRL	Now called V-2 Upper Atmosphere Panel. Panel begins practice of hearing reports on firings and research results.
4	3 June 46	APL	-
5	9 July 46	GE	-
6	5 Sept. 46	WL	Now called V-2 Upper Atmosphere Research Panel.
7	4 Nov. 46	ESL	-
8	28 Jan. 47	NRL	-
9	25 Mar. 47	PF	JRDB requests long range plans from panel.
10	7 May 47	APL	-
11	3 July 47	WSPG	-
12	1 Oct. 47	GE	Aerobee test firings have started. Panel promotes symposium on high-altitude physical research by rockets, to be held at American Physical Society meetings in Chicago. 29-31 Dec. 1947.
13	29 Dec.47	Chi.	Krause resigns; Van Allen elected chairman. Office of Chief of Ordnance proposes panel consider broadening its scope.
14	28 Jan. 48	NRL	-
15	18 Mar. 48	ERL	Name changed to Upper Atmosphere Rocket Research Panel.
16	28 Apr. 48	ESL	-
17	16 June 48	APL	-
18	29 Sept. 48	WSPG	-
19	5 Jan. 49	CIT	-
20	21 Apr. 49	UM	Van Allen has been using Aerobees fired from shipboard to extend geographic coverage of his research.
21	3 Aug. 49	HCO	Viking development is under way, and a first firing has been made.
22	26 Oct. 49	NRL	-
23	14 Feb. 50	APL	-
24	20 Apr. 50	NRL	Panel plans a coordinated set of high-altitude temperature experiments.
25	14 June 50	UC	***Sydney Chapman, British scientist, attends.***
26	8 Sept. 50	GE	Future research requirements and need for higher altitude vehicles considered.
27	31 Jan. 51	NRL	-
28	25 Apr. 51	NRL	***Panel begins discussions that lead to publication of panel paper on properties of upper atmosphere in Physical Review.***

[459] From Newell, *Beyond the Atmosphere*, 424-426.

29	14,15 Aug. 51	URI	Panel conducts seminar on properties of atmosphere at high altitudes. ***Panel has been giving extensive consideration to sounding rocket firings at other locations than White Sands;*** Fort Churchill, Canada, is one of the possibilities being considered.
30	24 Oct. 51	UCh	-
31	8 Jan. 52	SUI	-
32	30 Apr. 52	MN	***Panel plans to accept invitation from Gassiot Committee to join symposium on upper atmosphere at Oxford in August 1953.***
33	7 Oct. 52	TN	Van Allen reports on use of balloon-launched rockets, called Rockoons. Panel is planning a symposium on rocket ionospheric studies.
34	29, 30 Jan. 53	PAFB	-
35	29 Apr. 53	TN	Panel is going in depth into plans for coordinated northern latitude firings.
36	7 Oct. 53	AFCRC	***Panel reviews results of international symposium on upper atmospheric research held at Oxford the preceding August. Panel discusses participation in IGY.***
37	4 Feb. 54	MN	Special Committee for the IGY (SCIGY) to work on Arctic firings is appointed.
38	29 Apr. 54	MN	Plans progressing for IGY rocket program.
39	8, 9 Sept. 54	NRL	Panel develops budget for IGY program.
40	3 Feb. 55	JPL	Panel votes to offer SCIGY to Technical Panel on Rocketry of National Academy of Sciences.
41	2 June 55	TN	***Panel data on upper atmosphere has been used in preparing proposed extension to ICAO Standard Atmosphere used in aeronautical design work.***
42	27 Oct. 55	BRL	Van Allen reports on Rockoon firings in auroral zone. Panel is planning symposium on scientific uses of earth satellites.
43	26, 27 Jan. 56	UM	***Symposium on scientific uses of earth satellites.***
44	31 May 56	P	***Panel hears reports on Japanese, Australian, British, and French rocket programs. IGY satellite plans are discussed.***
45	17 Dec. 56	NRC	Rocket firings are under way at Fort Churchill.
46	29 Apr. 57	NRL	***Panel changes its name to Rocket and Satellite Research Panel.***
47	19 Sept. 57	AFCRC	***Committee on the Occupation of Outer Space formed.***
48	13, 14 Nov. 57	UM	***Meeting devoted to report of COS, and to discussion of future of RSRP.***
49	6 Dec. 57	NAS	***Meeting devoted to planning RSRP's promotion of a National Space Establishment. Panel has been enlarged-about double.***
50	19 Dec. 57	UCh	***Meeting devoted to planning RSRP's activity in support of National Space Establishment.***
51	8 Jan. 58	NAS	***Meeting devoted to the promotion of National Space Establishment.***
52	14 Feb. 58	MN	***Meeting hears reports of progress on promoting National Space Establishment.***
53	2 Apr. 58	NAS	-
54	29 Jan. 59 (1959-1)	NASA	Panel discusses its future role; decides on series of colloquia.
55	10 Apr. 59	NASA	Colloquium on Van Allen Radiation Belt.

	(1959-2)		
56	15 June 59 (1959-3)	NAS	Symposium on IGY rocket and Satellite results.
57	6 Nov. 59 (1959-4)	NAS	Colloquiurn on ionosphere.
58	17 Feb. 60 (1960-1)	UM	Colloquium on magnetic storms and their relation to rocket and satellite research. Panel adopts formal constitution.
59	18,19 May 60 (1960-2)	SH	Review of panel firings and results.
PANEL SUSPENDS OPERATIONS			
60	2 Feb. 68 (1968-1)	JPL	Primarily to renew acquaintances. Secretary proposes to turn over panel files, when he finishes with them, to National Air and Space Museum, Smithsonian Institution, for archiving.

APPENDIX B
NATIONAL SPACE ESTABLISHMENT
A Proposal of the Rocket and Satellite Research Panel[460]

27 December 1957

Summary of Proposal

It is proposed that there be created a unified National Space Establishment for the purpose of carrying out the scientific exploration and eventual habitation of outer space.

It is imperative that the United States establish and maintain scientific and technological leadership in outer space research in the interests of long-term human progress and national survival.

1. Role

The role of the National Space Establishment shall be to unify and to greatly expand the national effort in outer space research, specifically excluding areas of immediate military urgency (e.g., the development, production and fielding of intercontinental and intermediate-range ballistic missiles).

2. Mission

The broad mission of the National Space Establishment shall be to establish United States leadership in space research by 1960 and to maintain it thereafter.

Accomplishment of this mission requires the following specific achievements:

> (a) An intensified program of scientific soundings with high altitude rockets, immediately.
>
> (b) An intensified program of scientific and technical developments with small instrumented satellites of the earth, immediately.
>
> (c) Impact on the moon with non-survival of apparatus, by 1959.
>
> (d) Placing an instrumented satellite in an orbit about the moon, by 1960.
>
> (e) Impact on the moon with survival of scientific instruments, by 1960.
>
> (f) Returnable, manned satellites in flight around the earth, by 1962.

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[460] From Newell, Beyond the Atmosphere, p. 430-432.

(g) Manned circumnavigation of the moon with return to the earth, by 1965.

(h) Manned permanent satellite, by 1965.

(i) Manned expedition to the moon by one or two men, by 1968.

(j) Manned expedition to the moon by a sizeable party of men, by 1971.

A thorough analysis of existing capabilities shows that all of these objectives are within reach of a unified, vigorous national effort.

3. Funds Required

A detailed analysis shows that the accomplishment of the basic mission will require a national expenditure of ten billion dollars over the next decade.

4. Administrative Status of National Space Establishment

(a) It is strongly desirable that the N.S.E. be given statutory status as an independent agency in order that its work can be freely directed toward broad cultural, scientific and commercial objectives. Such objectives far transcend the short term, though vitally important, military rocket missions of the Department of Defense.

(b) If the proper creation of an independent agency is judged to require an intolerable delay, then it is believed that statutory existence under the Secretary of Defense (but *not* within the jurisdiction of any one of the military services) will be a workable arrangement for the immediate future. But in this event, it is urged that the "charter" of the agency explicitly provide for its independence as soon as its stature and achievements make this advisable.

(c) It is explicitly advised that the National Space Establishment not be placed within the jurisdiction of any one of the three military services. There are many reasons, growing out of extensive professional experience, for this view. The military services are basically operating agencies, not research ones. The research talent of any branch of the military services is almost inevitably turned toward helping meet short term, limited objectives. Such a point-of-view would assure the failure of a National Space Establishment in its broad mission-which is truly a national one, far beyond the mission of any one of the services or of the Department of Defense taken as a whole. During the early phases of space research, it is evident that existing facilities and missile technology of the Department of Defense can make enormous contributions. The National Space Establishment must be set up in such a way that it enjoys the unqualified support of all three services, and not merely one of them. Such a situation is believed to be possible only if the N.S.E. is an independent agency from the outset or if it is directly responsible only to the Secretary of Defense during its early years-with the clear prospect of independence at the earliest possible date.

(d) There must be clear channels for mutual cooperation between the proposed N.S.E. and all levels of the Department of Defense, in order to assure no jeopardy of short term, vital military need on the one hand and in order to assure maximum rate of advance of space research on the other.

5. Remarks on the Long Range Importance of Space Research

It is already clear that international leadership hinges, to a very great extent, on preeminence in scientific and technological matters.

Space research will contribute enormously to the educational, cultural, and intellectual character of the people of the United States and of the world. Indeed, the exploration and eventual habitation of outer space are the finest examples of the "Endless Frontier". It is for such bold endeavors that the highest motives of men should be invoked.

There will be a rich and continuing harvest of important practical applications as the work proceeds. Some of these can already be foreseen-reliable short term and long term meteorological forecasts, with all the agricultural and commercial advantages that these imply; rapid, long range radio communications of great capacity and reliability; aids to navigation and to long range surveying; television relay; new medical and biological knowledge, etc. And these will be only the beginning. Many of these applications will be of military value; but their greater value will be to the civilian community at large. (To use a homely example, the telephone is certainly a valuable military device, but its importance to the civilian population is vastly greater.)

6. Availability of the Rocket and Satellite Research Panel for Consultation and Participation

The Rocket and Satellite Research Panel comprises a broad membership of persons of extensive experience in all aspects of the proposed program of outer space research. Its members are professionally dedicated to national leadership in this field. They offer their services, individually and collectively, in the conduct of the broad mission of the National Space Establishment.

[431-432] The Rocket and Satellite Research Panel	
Berning, W. W.	Army Ballistics Research Lab.
Delsasso, L. A.	Army Ballistics Research Lab.
Dow, W. G.	University of Michigan
Ehricke, K.	Convair Corp.
Ference, M.	Ford Research Laboratory
Green, C. F.	General Electric Co.
Greenberg, M.	AF Cambridge Research Center
Jones, L. M.	University of Michigan

Kaplan, J.	University of California
Kellogg, W. W.	Rand Corp.
Newell, H. E.	Naval Research Laboratory
Nichols, M. H.	University of Michigan
O'Day, M. D.	AF Cambridge Research Center
Pickering, W. H.	Jet Propulsion Laboratory
Spencer, N. W.	University of Michigan
Stehlink, K.	Naval Research Laboratory
Stewart, H. J.	Jet Propulsion Laboratory
Stroud, W. G.	Army Signal Engineering Lab.
Strughold, H.	Randolph AFB
Stuhlinger, E.	Army Ballistic Missile Agency
Townsend, J. W.	Naval Research Laboratory
Van Allen, J. A., Chairman	University of Iowa
Von Braun, W.	Army Ballistic Missile Agency
Whipple, F. L.	Smithsonian Astrophysical Obs.
Wyckoff, P. H.	AF Cambridge Research Center
Zelikoff, M.	AF Cambridge Research Center
Megerian, G. K., Secretary	General Electric Co.

BIBLIOGRAPHY

Adams, Valerie L. *Eisenhower's Fine Group of Fellows: Crafting a National Security Policy to Uphold the Great Equation*. Lanham, MD: Lexington Books, 2006.

Adas, Michael. *Dominance by Design: Technological Imperatives and America's Civilizing Mission.* Cambridge, Massachusetts: The Belknap Press of Harvard University Press, 2006.

Allen, William H., ed. *Dictionary of Technical Terms for Aerospace Use (First Edition).* Washington, D.C.: U.S. Government Printing Office, 1965. NASA SP-7.

Bates, Charles C., and John F. Fuller. *America's Weather Warriors: 1814-1985*. College Station, TX: Texas A&M University Press, 1986.

Belinsky, V.A., and V.A. Pobiyakho. *Aerology*. Jerusalem: Israel Program for Scientific Translations, 1967.

Biagioli, Mario, ed. *The Science Studies Reader*. New York, NY: Routledge, 1999.

Bille, Matt, and Erika Lishock. *The First Space Race: Launching the World's First Satellites*. College Station, TX: Texas A&M University Press, 2004.

Bilstein, Roger E. *The American Aerospace Industry: From Workshop to Global Enterprise*. New York, NY: Twayne Publishers, 1996.

Borgwardt, Elizabeth. *A New Deal for the World: America's Vision for Human Rights*. Cambridge, MA: The Belknap Press of Harvard University Press, 2005.

Bowie, Robert R., Richard H. Immerman. *Waging Peace: How Eisenhower Shaped an Enduring Cold War Strategy*. Oxford, UK: Oxford University Press, 1998.

Boyer, Paul. *By the Bomb's Early Light: American Thought and Culture at the Dawn of the Atomic Age.* Chapel Hill, North Carolina: The University of North Carolina Press, 1994.

Boyd, R.L.F., ed. *Rocket Exploration of the Upper Atmosphere: Special Supplement (Vol. 1) to the Journal of Atmospheric and Terrestrial Physics*. New York, NY: Interscience Publishers, Inc., 1954.

Bulkeley, Rip. *The Sputniks Crisis and Early United States Space Policy: A Critique of the Historiography of Space*. Bloomington, IN: Indiana University Press, 1991.

Bush, Vannevar. *Modern Arms and Free Men: A Discussion of the Role of Science in Preserving Democracy*. New York, NY: Simon and Schuster, 1949.

Bush, Vannevar. *Science: The Endless Frontier: Report to the President on a Program for Postwar Scientific Research*. Washington, D.C.: U.S. Government Printing Office, 1945.

Carlisle, Rodney P. *Management of the U.S. Navy Research and Development Centers During the Cold War: A Survey Guide to Reports*. Washington, D.C.: Navy Laboratory/Center Coordinating Group and the Naval Historical Center, 1996.

Carlisle, Rodney P. *Navy RTD&E Planning in an Age of Transition: A Survey Guide to Contemporary Literature*. Washington, D.C.: Navy Laboratory/Center Coordinating Group and the Naval Historical Center, 1997.

Chernus, Ira. *Eisenhower's Atoms for Peace*. College Station, TX: Texas A&M University Press, 2002.

Clarke, Sally H., Naomi R. Lamoreaux, Steven W. Usselman, eds. *The Challenge of Remaining Innovative: Insights from Twentieth-Century American Business.* Stanford, California: Stanford Business Books, 2009.

Collins, Martin J. *Cold War Laboratory: RAND, thew Air Force, and the American State, 1945-1950.* Washington, D.C., Smithsonian Institution Press, 2002.

Condit, Doris M. *The Test of War, 1950-1953*. Washington, D.C.: U.S. Government Printing Office, 1988.

Crow, Michael, and Barry Bozeman. *Limited by Design: R&D Laboratories in the U.S. National Innovation System.* New York, NY: Columbia University Press, 1998.

Decade of Basic and Applied Science in the Navy, A: A Symposium Sponsored by the Office of Naval Research as Part of its Decennial Year, March 19 and 20, 1957. Washington, D.C.: U.S. Government Printing Office, 1957. ONR-2.

DeVorkin, David H. *Science with a Vengeance: How the Military Created the U.S. Space Sciences After World War II*. New York, NY: Springer-Verlag, 1992.

Dick, Steven J., ed. *NASA's First 50 Years: Historical Perspectives*. Washington, D.C.: U.S. Government Printing Office, 2010. NASA SP-2010-4704.

Donner, Leo: Wayne Schubert, and Richard Somerville, eds. *The Development of Atmospheric General Circulation Models: Complexity, Synthesis and Computation*. Cambridge, MA: Cambridge University Press, 2011.

Dunar, Andrew J., and Stephen P. Waring. *Power to Explore: A History of Marshall Space Flight Center, 1960-1990*. Washington, D.C.: U.S. Government Printing Office, 1999. NASA SP-4313.

Emme, Eugene M. *Aeronautics and Astronautics: An American Chronology of Science and Technology in the Exploration of Space, 1915-1960*. Washington, D.C.: U.S. Government Printing Office, 1961.

Engerman, David C., Nils Gilman, Mark H. Haefele, and Michael E. Latham, eds. *Staging Growth: Modernization, Development, and the Global Cold War.* Amherst, Massachusetts: University of Massachusetts Press, 2003.

Ferguson, Niall; Charles S. Maier, Erez Manela, and Daniel S. Sargent, eds. *The Shock of the Global: The 1070s in Perspective*. Cambridge, Massachusetts: The Belknap Press of Harvard University Press, 2010.

Fleming, James Rodger. *Fixing the Sky: The Checkered History of Weather and Climate Control*. New York, NY: Columbia University Press, 2010.

Friedman, Robert Marc. *Appropriating the Weather: Wilhelm Bjerknes and the Construction of a Modern Meteorology*. Ithaca, NY: Cornell University Press, 1989.

Frutkin, Arnold W. *International Cooperation in Space*. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1965.

Gaddis, John Lewis. *The Cold War: A New History*. New York, NY: The Penguin Press, 2005.

Gaddis, John Lewis. *The Long Peace: Inquiries into the History of the Cold War*. New York, NY: Oxford University Press, 1987.

Galambos, Louis. *The Creative Society – and the Price Americans Paid for It*. Cambridge, MA: Cambridge University Press, 2012.

Gallison, Peter, and Bruce Hevly, eds. *Big Science: The Growth of Large-Scale Research. Stanford,* California: Stanford University Press, 1992.

Golley, Frank Benjamin. *A History of the Ecosystem Concept in Ecology: More than the Sum of the Parts*. New Haven, Connecticut: Yale University Press, 1993.

Grandin, Karl, Nina Wormbs, and Sven Widmalm. *The Science-Industry Nexus: History, Policy, Implications*. Sagamore Beach, WA: Science History Publications, 2004.

Green, Constance McLaughlin, and Milton Lomask. *Project Vanguard: The NASA History*. Mineola, NY: Dover Publications, Inc., 2009.

Gruntman, Mike. *Blazing the Trail: The Early History of Spacecraft and Rocketry*. Reston, VA: The American Institute of Aeronautics and Astronautics, Inc., 2004.

Hanle, Paul A., and Von Del Chamberlain, eds. *Space Science Comes of Age: Perspectives in the History of the Space Sciences.* Washington, D.C.: Smithsonian Institution Press, 1981.

Harper, Kristine C. *Weather by the Numbers: The Genesis of Modern Meteorology*. Cambridge, Massachusetts: The MIT Press, 2008.

Hart, Justin. *Empire of Ideas: The Origins of Public Diplomacy and the Transformation of U.S. Foreign Policy*. New York, NY: Oxford University Press, 2013

Hughes, Thomas P. *American Genesis: A Century of Innovation and Technological Enthusiasm, 1870-1970*. New York, NY: Viking Press, 1989.

Hughes, Thomas P. *Rescuing Prometheus.* New York, NY: Pantheon Books, 1998.

Johnson, Stephen B. *The Secret of Apollo: Systems Management in American and European Space Programs.* Baltimore, Maryland: The Johns Hopkins University Press, 2002.

Killian, Jr., James R. *Sputnik, Scientists, and Eisenhower: A Memoir of the First Special Assistant to the President for Science and Technology.* Cambridge, Massachusetts: The MIT Press, 1977.

Krige, John, Angelina Long Callahan, and Ashok Maharaj. *NASA in the World*. New York, NY: Palgrave Macmillan, 2013.

Latham, Michael E. *Modernization as Ideology: American Social Science and "Nation Building" in the Kennedy Era.* Chapel Hill, North Carolina: The University of North Carolina Press, 2000.

Launius, Roger D., James Rodger Fleming, and David H. DeVorkin, eds. *Globalizing Polar Science: Reconsidering the International Polar and Geophysical Years.* New York, NY: Palgrave MacMillan, 2010.

Launius, Roger D. *NASA: A History of the U.S. Civil Space Program.* Malabar, Florida: Krieger Publishing Company, 1994.

Launius, Roger D., ed. *Organizing for the Use of Space: Historical Perspectives on a Persistent Issue*. San Diego, CA: American Astronautical Society Publications Office, 1995.

Launius, Rodger D., John M. Logsdon, and Robert W. Smith, eds. *Reconsidering Sputnik: Forty Years Since the Soviet Satellite.* New York, NY: Routledge, 2002.

Launius, Roger D., and Howard E. McCurdy, eds. *Spaceflight and the Myth of Presidential Leadership*. Urbana, IL: University of Illinois Press, 1997.

Leffler, Melvyn P. *For the Soul of Mankind: The United States, the Soviet Union, and the Cold War.* New York, NY: Hill and Wang, 2007.

Lenoir, Timothy. *Instituting Science: The Cultural Production of Scientific Disciplines*. Stanford, CA: Stanford University Press, 1997.

Leslie, Stuart W. *The Cold War and American Science: The Military-industrial-academic Complex at MIT and Stanford*. New York, NY: Columbia University Press, 1993.

Levering, Ralph B. *The Cold War: A Post-Cold War History.* Wheeling, Illinois: Harlan Davidson, Inc., 1994.

Logsdon, John M., ed. *Exploring the Unknown, Selected Documents in the History of the U.S. Civil Space Program, Volume I: Organizing for Exploration*. Washington, D.C.: U.S. Government Printing Office, 1998. NASA SP-4407.

Logsdon, John M., ed. *Exploring the Unknown, Selected Documents in the History of the U.S. Civil Space Program, Volume III: Using Space*. Washington, D.C.: U.S. Government Printing Office, 1998. NASA SP-4407.

Ludwig, George H. *Opening Space Research: Dreams, Technology, and Scientific Discovery*. Washington, D.C.: American Geophysical Union, 2011.

Mack, Pamela E. *From Engineering Science to Big Science: The NACA and NASA Collier Trophy Research Project Winners*. Washington, D.C.: U.S. Government Printing Office, 1998. NASA SP-4219.

Mack, Pamela E. *Viewing the Earth: The Social Construction of the LandSat Satellite System*. Cambridge, MA: The MIT Press, 1990.

MacKenzie, Donald. *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance*. Cambridge, MA: The MIT Press, 1993.

Markusen, Ann; Peter Hall, Scott Campbell, and Sabina Deitrick. *The Rise of the Gunbelt: The Military Remapping of Industrial America*. New York, NY: Oxford University Press, 1991.

Massey, Harrie; and M.O. Robins. *History of British Space Science*. Cambridge, MA: Cambridge University Press, 1986.

Massey, H.S.W., and R.L.F. Boyd. *The Upper Atmosphere*. New York, NY: Philosophical Library, Inc., 1959.

McCurdy, Howard E. *Inside NASA: High Technology and Organizational Change in the U.S. Space Program*. Baltimore, MD: The Johns Hopkins University Press, 1993.

McDougall, Walter A. *...the Heavens and the Earth: A Political History of the Space Age*. New York, NY: Basic Books, Inc., 1985.

McNeill, J.R., and Corinna R. Unger, eds. *Environmental Histories of the Cold War.* Cambridge, Massachusetts: Cambridge University Press, 2010.

Melman, Seymour, ed. *The War Economy of the United States: Readings in Military Industry and Economy*. New York, NY: St. Martin's Press, 1971.

Mieczkowski, Yanek. *Eisenhower's Sputnik Moment: The Race for Space and World Prestige*. Ithaca, NY: Cornell University Press, 2013.

Miller, Clark A., and Paul N. Edwards, eds. *Changing the Atmosphere: Expert Knowledge and Environmental Governance*. Cambridge, MA: The MIT Press, 2001.

Mokyr, Joel. *The Gifts of Athena: Historical Origins of the Knowledge Economy.* Princeton, New Jersey: Princeton University Press, 2002.

Morgan, Iwan W. *Eisenhower Versus the Spenders*. London, UK: Pinter Publishers, 1990.

National Research Council. *Fair Weather: Effective Partnerships in Weather and Climate Services*. Washington, D.C.: The National Academies Press, 2003.

Naugle, John E. *First Among Equals: The Selection of NASA Space Science Experiments*. Washington, D.C.: U.S. Government Printing Office, 1991. NASA SP-4215.

Nebeker, Frederick. *Calculating the Weather: Meteorology in the 20th Century*. San Diego, CA: Academic Press, 1995.

Needell, Allan A. *Science, Cold War, and the American State: Lloyd V. Berkner and the Balance of Professional Ideas.* Amsterdam, The Netherlands: Harwood Academic Publishers, 2000.

Neufeld, Michael J. *The Rocket and the Reich: Peenemunde and the Coming of the Ballistic Missile Era*. Cambridge, MA: Harvard University Press, 1995.

Neufeld, Michael J. *Von Braun: Dreamer of Space, Engineer of War*. New York, NY: Alfred A. Knopf, 2007.

Newell, Homer E. *Beyond the Atmosphere: Early Years of Space Science.* Washington, D.C.: U.S. Government Printing Office, 1980. NASA SP-4211.

Nye, Jr., Joseph S. *The Paradox of American Power: Why the World's Only Superpower Can't Go it Alone*. Oxford, UK: Oxford University Press, 2002.

Nye, Jr., Joseph S. *Soft Power: The Means to Success in World Politics*. New York, NY: Public Affairs, 2004.

Ordway III, Frederick I., and Mitchell R. Sharpe. *The Rocket Team: From the V-2 to the Saturn Moon Rocket – the Inside Story of How a Small Group of Engineers Changed World History*. New York, NY: Thomas Y. Crowell, Publishers, 1979.

Parson, Jr. Nels A. *Missiles and the Revolution in Warfare*. Cambridge, MA: Harvard University Press, 1962.

Pickering, Andrew. *The Mangle of Practice: Time, Agency, and Science.* Chicago, Illinois: The University of Chicago Press, 1995.

Roland, Alex. *The Military-industrial Complex*. Washington, D.C.: The Society for the History of Technology and the American Historical Association, 2001.

Roland, Alex. *Model Research: The National Advisory Committee for Aeronautics, 1915-1958. Volume 1.* Washington, D.C.: U.S. Government Printing Office, 1985. NASA SP-4103.

Rosen, Milton W. *The Viking Rocket Story*. New York, NY: Harper & Brothers, Publishers, 1955.

Rosenbloom, Richard S., and William J. Spencer, eds. *Engines of Innovation: U.S. Industrial Research at the End of an Era*. Boston, MA: Harvard Business School Press, 1996.

Rosenthal, Alfred. *Venture into Space: Early Years of Goddard Space Flight Center*. Washington, D.C.: U.S. Government Printing Office, 1968. NASA SP-4301.

Sapolsky, Harvey M. *Science and the Navy: The History of the Office of Naval Research*. Princeton, NJ: Princeton University Press, 1990.

Scott, James C. *Seeing Like a State: How Certain Schemes to Improve the Human Condition have Failed.* New Haven, Connecticut: Yale University Press, 1998.

Siddiqi, Asif A. *Sputnik and the Soviet Space Challenge*. Gainesville, FL: University Press of Florida, 2000.

Siddiqi, Asif A. *The Soviet Space Race with Apollo*. Gainesville, FL: The University Press of Florida, 2000.

Smith, Merritt Roe, ed. *Military Enterprise and Technological Change: Perspectives on the American Experience.*Cambridge, Massachusetts: The MIT Press, 1987.

Smith, Robert W. *The Space Telescope: A Study of NASA, Science, Technology, and Politics*. Cambridge, MA: Cambridge University Press, 1989.

Stares, Paul B. *The Militarization of Space: U.S. Policy, 1945-84*. Ithaca, New York: Cornell University Press, 1985.

Temple III, L. Parker. *Shades of Gray: National Security and the Evolution of Space Reconnaissance*. Reston, VA: American Institute of Aeronautics and Astronautics, Inc., 2005.

Thagaard, Tove. *Scientific Communities.* Oslo: University of Oslo, 1986.

Thomas, Sirley. *Satellite Tracking Facilities: Their History and Operation*. New York, NY: Holt, Rinehart and Winston, Inc., 1963.

Trachtenberg, Marc. *History & Strategy*. Princeton, NJ: Princeton University Press, 1991.

Tsiao, Sunny. *"Read You Loud and Clear!": The Story of NASA's Spaceflight Tracking and Data Network.* Washington, D.C.: U.S. Government Printing Office, 2008. NASA SP-2007-4232.

van Straten, Florence W. *Weather or Not*. New York, NY: Dodd, Mead & Company, 1966.

Vetter, Jeremy, ed. *Knowing Global Environments: New Historical Perspectives on the Field Sciences*. New Brunswick, NJ: Rutgers University Press, 2011.

Vining, Margaret, and Barton C. Hacker. *Science in Uniform, Uniforms in Science: Historical Studies of American Military and Scientific Interactions*. Lanham, MD: Smithsonian National Museum of American History, 2007.

Von Bencke, Matthew J. *The Politics of Space: A History of U.S.-Soviet/Russian Competition and Cooperation in Space*. Boulder, CO: Westview Press, 1997.

Wang, Jessica. *American Science in an Age of Anxiety: Scientists, Anticommunism, and the Cold War.* Chapel Hill, North Carolina: The University of North Carolina Press, 1999.

Wang, Zuoyue. *In Sputnik's Shadow: The President's Science Advisory Committee and Cold War America*. New Brunswick, New Jersey: Rutgers University Press, 2008.

Westad, Odd Arne. *Reviewing the Cold War: Approaches, Interpretations, Theory*. London: Frank Cass Publishing, 2000.

Westad, Odd Arne. *The Global Cold War*. Cambridge, Massachusetts: Cambridge University Press, 2007.

Westwick, Peter J. *The National Labs: Science in an American System, 1947-1974.* Cambridge, Massachusetts: Harvard University Press, 2003.

Widger, Jr., William K. *Meteorological Satellites.* New York, NY: Holt Rinehart, and Winston, Inc., 1966.

Williams, Kathleen Broome. *Improbable Warriors: Women Scientists and the U.S. Navy in World War II.* Annapolis, Maryland: Naval Institute Press, 2001.

Wilson, J. Tuzo. *I.G.Y.: The Year of the New Moons*. Toronto, Canada: Longmans, Green, and Co., 1961.

Whitnah, Donald R. *A History of the United States Weather Bureau*. Urbana, IL: University of Illinois Press, 1961.

Zachary, G. Pascal. *Endless Frontier: Vannevar Bush, Engineer of the American Century*. New York, NY: The Free Press, 1997.

Zahl, Harold A. *Radar Spelled Backwards*. New York, NY: Vantage Press, 1972.